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The development of a computerised information retrieval system for decorative plant selection.

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THE DEVELOPMENT OF A COMPUTERISED INFORMATION RETRIEVAL SYSTEM FOR DECORATIVE PLANT SELECTION

submitted by James Donald Hitchmough
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CONTENTS

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Abstract

The development of a computerised information retrieval system called Hortbase is described. Hortbase has been designed to meet the information needs of the professions involved with decorative plant usage in the landscape, and is composed of two constituent databases, Plantbase and Climatebase. Plantbase supplies information on the environmental tolerances, husbandry requirements and morphological and aesthetic characteristics of decorative plants. Climatebase provides information on key climatic limitations to plant growth and development for any planting location in England and Wales.

The design of the databases and the quantification of climatic factors and plant characteristics is discussed together with the influence of factors such as traditional information sources, fashion, plant availability, and contemporary cultivation thought and practice in determining plant use and success in the landscape.

1. Introduction

The objective of this study is to investigate the feasibility of a computer based storage and controlled retrieval system as a means of providing information on decorative plants "hardy" in England and Wales.

The outcome of this work is a system comprising two databases and a user handbook, together called "Hortbase". Hortbase attempts to document the characteristics of plants suitable for landscape planting in the widest sense, thus the system may be of interest to, amongst others, amenity horticulturalists, architects, and landscape architects. The range of characteristics is extensive and covers the nomenclature, morphology, cultivation and environmental tolerances of every plant entered. Certain aspects of plant performance are considered both in isolation, and in relation to the climate of England and Wales.

At the time of the projects conception, the value of computerised information retrieval had already been recognised in other areas of technology and science (John, Van Laerhoven & Sprout 1972, Johnston & Gray 1977, Magrill 1978, Cotter, Machardy & Warren 1979, Thompson & Baum 1979) and in the plant sciences this was especially evident in the computerisation of Botanic Garden Catalogues (Zander 1977, Hunt 1978).

In addition to sharing some of the objectives of the Botanical Collections databases, Hortbase also attempts to reappraise existing information and document the often complex relationships that determine the success or failure of decorative plants in the landscape. This thesis argues that the current sources of information used by practitioners of landscape design, construction and management are inadequate, both in terms of content and perspective, and accordingly Hortbase is intended to be more than just a source of descriptive information.

This need to quantify other than morphological data requires an understanding of the phenomena which determine a plants performance in the landscape, that is, the characteristics of the plant, the environment of the planting site, and the cultivation input available.

Within these terms of reference the author saw his role as that of the designer of a system which could provide answers to the problems produced by these interactions, to allow practitioners to acheive successful plant phenotypes in the landscape. This fundamental objective is the raison d'etre for the development of Hortbase. This thesis examines the determinants of success, and the means by which an attempt was made to identify, quantify and record these within the body of a computer retrieval system.

2. Mans Association with Decorative Plants

Mans interest in non edible plants spans at least four millenia (Jellicoe & Jellicoe 1975). Throughout this period the primary function of decorative plants has been to improve the quality of an environment.

The beneficiaries have ranged from clearly identifiable individuals or small groups to society in general. As the "benefit" conferred is frequently perceived differentially by the individuals within a user group, the value derived from the provision of decorative plants remains a contentious issue. Decorative plants may be used primarily as structural or aesthetic elements in the landscape or more frequently as a combination of both.

Typical functional uses are as follows:

a) To define spaces by the use of perimeter masses of vegetation.
b) To provide shelter by reducing wind velocity.
c) To screen or divert the eye from undesirable objects.
d) To act as structural elements to stabilise surfaces and minimise erosion.
e) To provide shade and reduce air temperatures
f) To provide a habitat for wildlife
g) To demarcate pedestrian and vehicular routes
h) To reduce noise and chemical pollution though these effects are often largely psychological

The aesthetic value of plantings are dominantly visual providing colour, light and shade, form and texture. In addition plantings produce pleasant sounds and scents, and even the feel of vegetation may be pleasant. Above all plants contribute to our sense of beauty in space and time.

Through a combination of the above uses plants create mood and atmosphere and impart dynamic qualities to the landscape. In Britain a far wider range of decorative plants have been used to acheive these objectives than in probably any other country in the world. Although not all are in contemporary usage, a conservative estimate would suggest that in excess of 17,000 decorative taxa are cultivated outdoors in the British Isles. (Synge 1961, Hillier 1974, Thomas 1976, Ingwersen 1978, Gault & Synge 1980).

This vast assemblage of decorative taxa dwarfs the national collections of many other nations. It is maintained to a considerable degree by individual amateur gardeners as well as by local and national governments and botanical institutions.

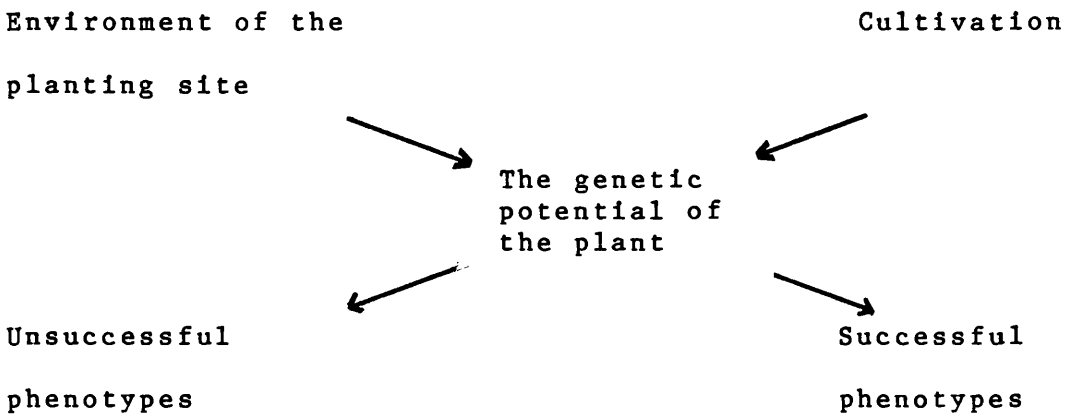
As discussed later in the Thesis the phenomenon of the amateur cultivator has exerted a considerable influence on the selection and usage of decorative plants in the British landscape. This broad based involvement may have contributed to the traditional lack of a distinct separation between public and institutional landscape and private garden design. This separation is now becoming clear in Britain although it has been evident in some other European countries for many years.

These historical and cultural influences are in turn reflected in the nature of the decorative plant literature available to and used by contemporary landscape practitioners. This situation is examined in greater detail in 4.1.

2.1 The Concept of Cultivation

Cultivation is the technology by which this assemblage of decorative plants have been maintained. It is a combination of management decisions and practical work by which satisfactory specimens of a large number of hardy decorative plants have been obtained.

Fig 2.1 Key Interactions that Determine the Success of a Decorative Plant in the Landscape



There are often great dissimilarities between the environment of the planting site and the cultivated plants natural habitat. This being so it may at first seem surprising that many plants grow as well or even better in cultivation than in the wild. This may be explained in part by the seemingly poor fit between the conditions prevailing upon many wild plants and the species physiological optima.

In nature factors such as mineral deficiencies, and interspecific competition frequently exclude plants from otherwise desirable locations, hence species may occupy locations that are markedly sub-optimal. (Fitter & Hay 1981)

Accordingly many such plants can respond dramatically when some of these limitations are removed or alleviated by cultivation. An excellent example of this is provided by the genus Eucalyptus which frequently exhibits greatly improved growth outside Australia due to higher levels of soil nitrogen and phosphor us, and reduced predation from foliage eating insects (Pryor 1976).

2.1.1 Cultivation Requirements in Relation to Plant Origin

All plants have basic environmental requirements outside which they cannot survive. Typically a constituent factor has a threshold below which that factor is inadequate, and an upper threshold beyond which additional increments of that factor are detrimental. In such cases the physiological optima lies somewhere between these two points.

A plants natural distribution is partly controlled by, and must fall within a climate exhibiting a satisfactory fit for its physiological demands and tolerances. By the same logic this must be true of a planting site for a cultivated specimen. If this principle is considered as an environmental constraint upon a species then subspecific variations which exhibit different physiological tolerances can be seen as mechanisms that allow a species to spread. Such naturally selected subspecific variants (ecotypes or provenances) are recognised and valued by commercial forestry (Lines & Mitchell 1965, Lines 1974). It follows that tolerance to conditions in different planting sites may vary between different ecotypes of a species (Green 1969). This suggests that plant selection at the subspecific level could be of value in landscape plants. This approach is readily handled by a rationalised concept of cultivation such as Hortbase. Unfortunately the cultivated specimens of most decorative species comprise an unknown mixture of ecotypes hence this approach is at present rarely possible.

This environmentally selected source of tolerance to disparate planting site environments may be further extended by a plants capacity to exhibit phenotypic plasticity. Most plants have this capacity to some degree and in some taxa it can be extreme. Phenotypic plasticity is a reversible survival mechanism involving morphological, physiological and biochemical changes which in nature allow plants to tolerate or more accurately to avoid damage as a result of exposure to environmental stress.

Phenotypic plasticity does not necessarily confer tolerance of a wide range of environmental factors, for example a plant may be highly tolerant of adverse substrate conditions whilst remaining extremely intolerant of localised shading. This is commonly the case with pioneer species such as Betula pendula.

Although phenotypic plasticity confers an ability to tolerate certain adverse environmental factors, it will only be of advantage to the landscape practitioner if the appearance and or performance of the plant is not unduly changed. For example perennial herbs which respond to stress by acting as facultative annuals may be pursuing a highly successful survival strategy, but are unlikely to be considered satisfactory in cultivation.

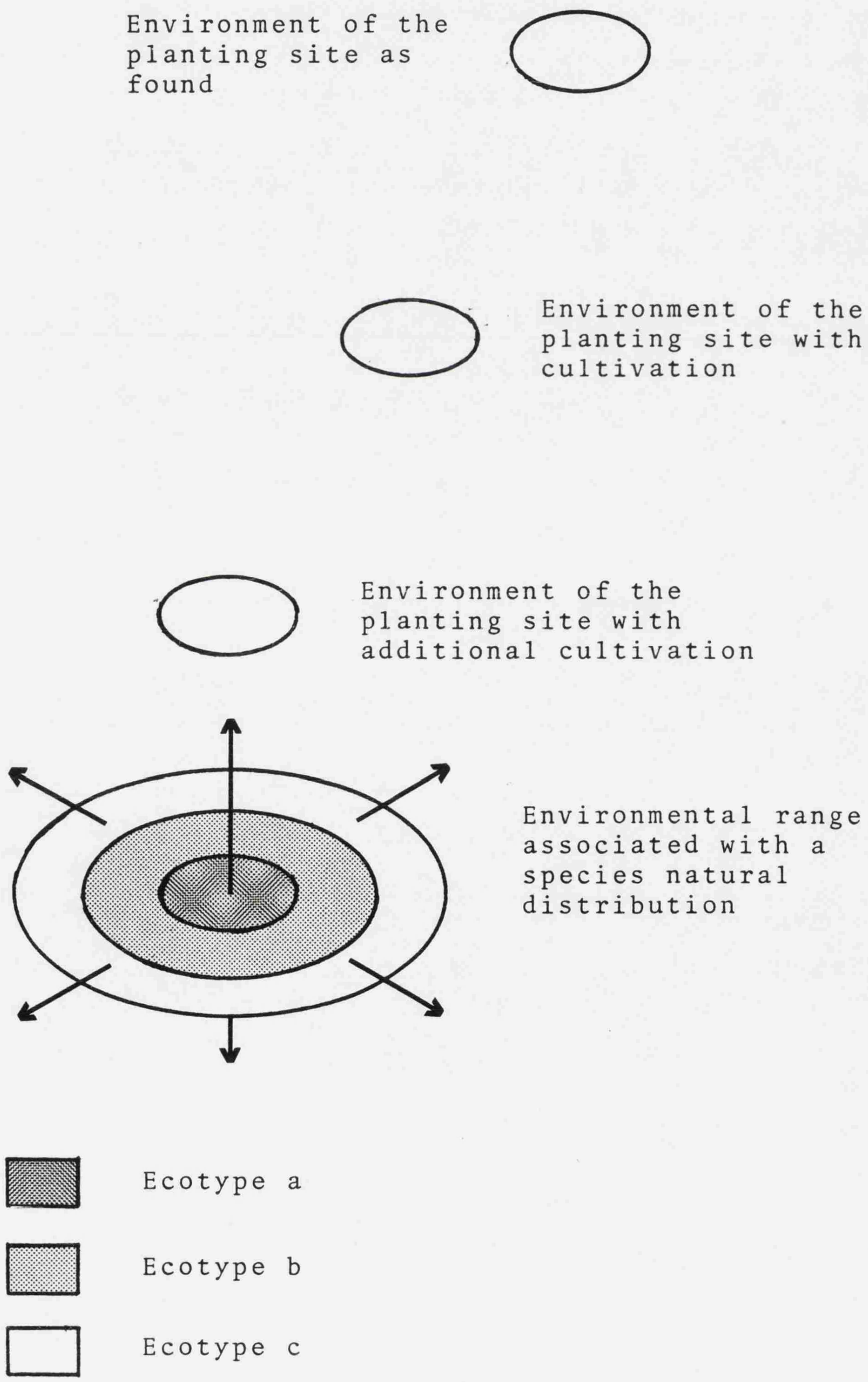
It seems logical that where a good fit between a plants requirements and site conditions are unobtainable the plant must be rejected. As the project is primarily concerned with the landscape of institutions and public open space it must be recognised that in contrast to private gardens husbandry can rarely be used to overcome or narrow this discrepancy. These ideas are fundamental to the concept of decorative plant performance in the landscape developed in this study and are examined further in 3.2.

Table 2.1 <u>The Response of Cultivated Plants to Favourabililty/Unfavourability of the Planting Site</u>

Similarity of the planting site environment to that of the natural habitat	Response of the cultivated specimen
High	Phenotype morphology corresponds closely to that exhibited by wild populations
Intermediate	Some phenotypic modification from typical wild type
Low	Death or extreme phenotypic modification

The relationships between the environment of the planting site, natural distribution and ecotypic races are summarised in Fig 2.2.

Fig 2.2 Influence of Ecotype and Cultivation on Environmental Fit



Nursery practices may have as important an effect on a cultivated plants performance as the subjects innate fitness to planting site. Many subjects offered for sale reflect the nurserymans most efficient way of utilising his resources rather than plants in the best biological condition to withstand the rigours of the site in question.

Generally woody plants of up to three years old are most capable of establishing in the landscape and producing satisfactory extension growth (Dunball 1978). This is especially the case on sub optimal planting sites. Above three years old bare root, field grown stock is likely to be checked following transplanting by unsatisfactory root: shoot ratios, and carbohydrate levels (Whitcomb 1983). In the case of larger container stock poor transplant development has been linked with root spiralling. Plants that have been thrown into "check" by nutrient and water deficiencies in the nursery, (as is often the case with poor container stock) are often difficult to release from this condition, irrespective of the suitability of the planting site (Harris 1971, Thoday 1982). The same applies to large, physiologically mature plants such as extra heavy trees, which following transplanting rarely acheive the extension growth characteristic of their species (Whalley 1979).

2.1.2 The Contemporary Role of Cultivation as Reflected in Hortbase

Traditional cultivation procedures remain the basis of much public landscape work. This sequence of horticultural practices has proved successful but often involves unnecessary elaboration or inputs. These practices arose in response to the challenge to grow the newly collected, previously unknown species which flooded into Western Europe in the nineteenth century. Not surprisingly the recipients of this material attempted to replicate their vision of the conditions under which the plant had been growing in the wild. This approach resulted in the complicated cultivation recipes found in the literature of the day (Anon 1882, Nicholson 1886).

Only with an increasing knowledge of plant physiology has it become widely recognised that the life processes of most plants are typically dependent on simple environmental factors, and that therefore a standardised regime which takes these crucial interactions into account can prove satisfactory for a large range of taxa irrespective of their ecological preferences. This has been amply demonstrated for plant root systems, by the success of the John Innes (Lawrence & Newell 1939) and subsequent peat based composts (Baker 1957).

It is fortunate that this is the case, as, as a result of current economic constraints, it is often no longer possible and certainly no longer desirable that unnecessary practices should continue to dominate cultivation thought and practice in contemporary landscapes.

In the light of current physiological knowledge, it is possible to rationalise cultivation techniques selecting only those which are essential or confer great benefit and discard the remainder. The prime aim of cultivation should be to modify the environment of the planting site till it falls within the tolerance range of the chosen taxa.

Table 2.2 Crucial Components of the Planting Site

Environmental component	Factors within the component which determine plant performance:
Climate	Solar radiation Air temperature Precipitation Average wind velocity
Site Substrate	Soil temperature Oxygen regime Available soil moisture Available nutrients Bulk density
Interspecific Competition	Available soil moisture Available nutrients Allelopathic responses Pathogens and predators

From Table 2.2 it is evident that some of the important factors are much less readily modified than others, for example, whilst weed competition can be readily suppressed by herbicides the climate of a site must be accepted largely as found, although significant microclimatic adjustments are sometimes feasible. Consequently a detailed assessment of the climate of the planting site is a prerequisite to both plant selection and the compilation of a husbandry programme.

2.1.3 Modification of the Environment by Cultivation.

Cultivation is normally directed to alter either or both the :

a) Physical environment

b) Biotic environment

It is generally directed to optimise one or more environmental factors in order to directly or indirectly "boost" a physiological or developmental process.

a)Physical Environment

In practice this largely concerns the amelioration of the substrate at the planting site, both in terms of physical and chemical properties. Specifically the objective is to produce a substrate with a satisfactory structure in terms of water and air holding capacity and permeable to root exploration (Perry 1982, Ruark, Mader & Tattar 1982). Both agricultural soils and superficially far less promising substrates possess such properties and for these to be satisfactory little or no amelioration is needed (Bradshaw 1982).

This concept of assessing growth substrates in terms of physical and chemical properties as opposed to geological origin and texture, is very appropriate to contemporary landscape activities which often occur on transported and or partially destroyed substrates.

This philosophy is reflected in Hortbase where plant response to growth substrates is primarily considered only in terms of tolerance of compacted anaerobic, and at other extreme excessively aerobic substrates. (see 7.7)

Recent work has suggested that substrates exhibiting satisfactory physical properties need not receive traditional pre-planting cultivations. However at present it appears that their omission is more often due to the scale of an operation or the prevailing economic climate and that this policy is adopted independant of the suitability of the substrate.

Failure to ameliorate a hostile substrate demands the selection of species best equipped to cope with such a potentially hostile environment.

Currently interest in the re-creation of certain indigenous plant communities has encouraged a move towards planting substrates that would have traditionally have been considered unacceptable for amenity plantings (Bos & Mol 1979).

b) Biotic Environment

Of the numerous factors covered by the phrase "biotic environment", by far the most important to amenity plantings is interspecific, (i.e. weed) competition.

For most cultivated taxa interspecific competition shortly after planting is a severe threat to plant establishment and even if this is acheived weed growth can prevent the desired phenotypic expression from developing.

Even in natural ecosystems it is frequently interspecific competition that determines species location, often compelling plants to occupy locations that are otherwise sub-optimal. This may be as a result of competition for light as in the case of Hyacinthoides non-scriptus (Blackman & Rutter 1946), or nutrients and water as for Deschampsia flexuosa. (Hackett 1965) The phenotypic expression of such plants is restricted as a consequence of competition for finite resources.

In cultivation, although competition for light may in certain situations constitute a problem, it may also be exploited in order to establish climax forest components that would otherwise prove difficult (Brown 1951). However the most important aspect of weed competition in the landscape is that which relates to competition for water and nutrient ions.

As Table 2.3 indicates, the "competitive index" of even dynamic, pioneer woody plants is low in comparison with the typical components of a herbaceous weed flora. Consequently this type of competition, especially during the establishment phase has a severely dehabilitating effect on woody plants. By controlling weed competition the amounts of water and nutrients available to recently planted subjects is greatly increased. (Messenger 1976, Fales & Wakefield 1981, Insley 1982)

Table 2.3 <u>Relative Growth Rates of Various Plants Grown Under Favourable Conditions, as a Surrogate Index of Competitive Capacity</u>. (data from Bannister 1976)

Plant	Relative Growth Rates in $g\ g^{-1}\ week^{-1}$
Fagus sylvatica	0.05
Pinus sylvestris	0.02
Poa annua	1.74
Populus tremula	0.92
Salix cinerea	1.06
Stellaria media	2.09

3. Decorative Plants Cultivated in Britain

3.1 Origins of Britains Cultivated Flora

As has been previously mentioned British decorative exotic horticulture is typified by the extreme richness of its flora which exceeds 17,000 taxa. Of this total approximately 8,000 are "hardy" woody plants, and most of the plant-climate-geological associations of the world outside the tropics and sub tropics are represented.

The size and diversity of this gene bank is due to a combination of an equable oceanic climate, British social history, and an expansionist foreign policy concurrent with a period of intense interest in botany and horticulture.

Widespread interest in the cultivation of decorative plants in Britain can perhaps be considered to have taken off in the late 18th century as a result of the patronage of plant collecting and cultivation by men of means. (Hadfield 1979).

The 19th century witnessed an enormous broadening of interest in, and support for, decorative plant introduction and cultivation. Even with this extension of the franchise the movement continued to be dominated by the most affluent sectors of society. As a result of the dramatic social changes Britain has experienced this

Note: the figure of 17,000 refers to hardy plants of value to contemporary landscape century, these forces are now largely spent, and their roles have largely been assumed by institutions and the less privileged amateur cultivator. Inevitably, as a result of these changes some taxa have been lost to cultivation although the increasing numbers of amateurs interested in decorative plants has permitted the retention of an incredibly large number of decorative taxa.

The majority of our decorative species were introduced to cultivation during the period 1700 to 1900 with the greatest influx in the latter half of the 19th century. This considerable range of taxa has since been supplemented by selection and hybridisation resulting in the present genepool of species and cultivars. Cultivar introduction has been taken to extreme lengths in some genera, e.g. Rhododendron, where over 500 cultivars are currently cultivated. (Hillier 1974)

3.1.1 Suitability and Availability of Taxa for Use in Landscape

Although a very large number of decorative taxa are cultivated in British gardens only a small percentage of this total are used in public greenspace.

As an indicator of current usage trends, only 10% of the woody taxa currently in cultivation have been identified by Britains Growers, Designers and Contractors liason organisation, as being of real value to contemporary landscape (JCLI 1978). Fewer still are in regular use.

This percentage is small because many of the cultivated taxa are or have been judged to be incapable of producing plants of acceptable quality under landscape conditions indeed there has grown up the notion of "garden plants" and "landscape plants".

Table 3.1 <u>Comparison of the Total Number of Cultivated Taxa with those Actually Available (Wholesale) to the Design Profession.</u>

Genus	Total in Cultivation in Britain	Available from 4 leading wholesale nurseries			
Berberis	139	63	28	21	25
Cotoneaster	98	53	20	10	18
Sorbus	98	53	31	14	15
Viburnum	106	53	24	20	16
	1	2	3	4	5

<u>Sources</u>
1 = Hilliers Manual Trees and Shrubs 1974
2 = Hillier Price list 1982-3
3 = Notcutts Book of Plants 1981
4 = Anglia Group Catalogue 1979-80
5 = Wyevale Good Plant Guide 1982

When assessing the landscape value of the cultivated gene pool plants can be conveniently divided into the following three categories:

a) "Satisfactory" i.e plants offering a high probability of achieving successful phenotypes under landscape conditions.

b) "Satisfactory if husbanded", plants which can be successful providing sufficient cultivation support is available.

c) "Unsatisfactory" i.e plants which offer an unacceptably high risk of failure under landscape conditions, irrespective of cultivation support.

The first group is typically composed of vigorous taxa which also possess a marked tolerance of unfavourable substrates and are generally well adapted to the climate of Britain, e.g native pioneer species such as Betula pendula, Alnus incana, Crataegus oxycantha. This group also includes many non-native but dynamic pioneer species such as Acer platanoides and A. pseudoplatanus.

The "Unsatisfactory" category typically possess one or more of the following characteristics:

a) They typically give rise to phenotypes of innately low quality

b) A low growth rate and or competitive index. Unfortunately many of the most stress tolerant shrubs cope by adopting the former strategy. This is a disadvantageous response from the landscape practitioners point of view.

c) The plant may show an extreme lack of fit between the environment of most public open space planting sites and its natural distribution (see 2.1.1). This incompatibility is often climate based, for example Hydrangea aspera subsp. villosa, is extremely sensitive to spring frosts whereas Embothrium coccineum is drought susceptible.

Responses such as these have encouraged the development of the database Climatebase (see Section 6) as a means of selecting suitable plant material through climatic criteria.

The group formed of those plants that can succeed with the aid of cultivation contains the largest number of taxa. These vary considerably in the level of cultivation input necessary to support them. For most members of this group success can be achieved through husbandry inputs such as soil preparation, weed control, and nutrient application. Typically these limiting factors are not ammended in landscape sites.

In all three categories cultivation can generally be used to further improve upon the level of performance providing immutable limiting factors are not already operating.

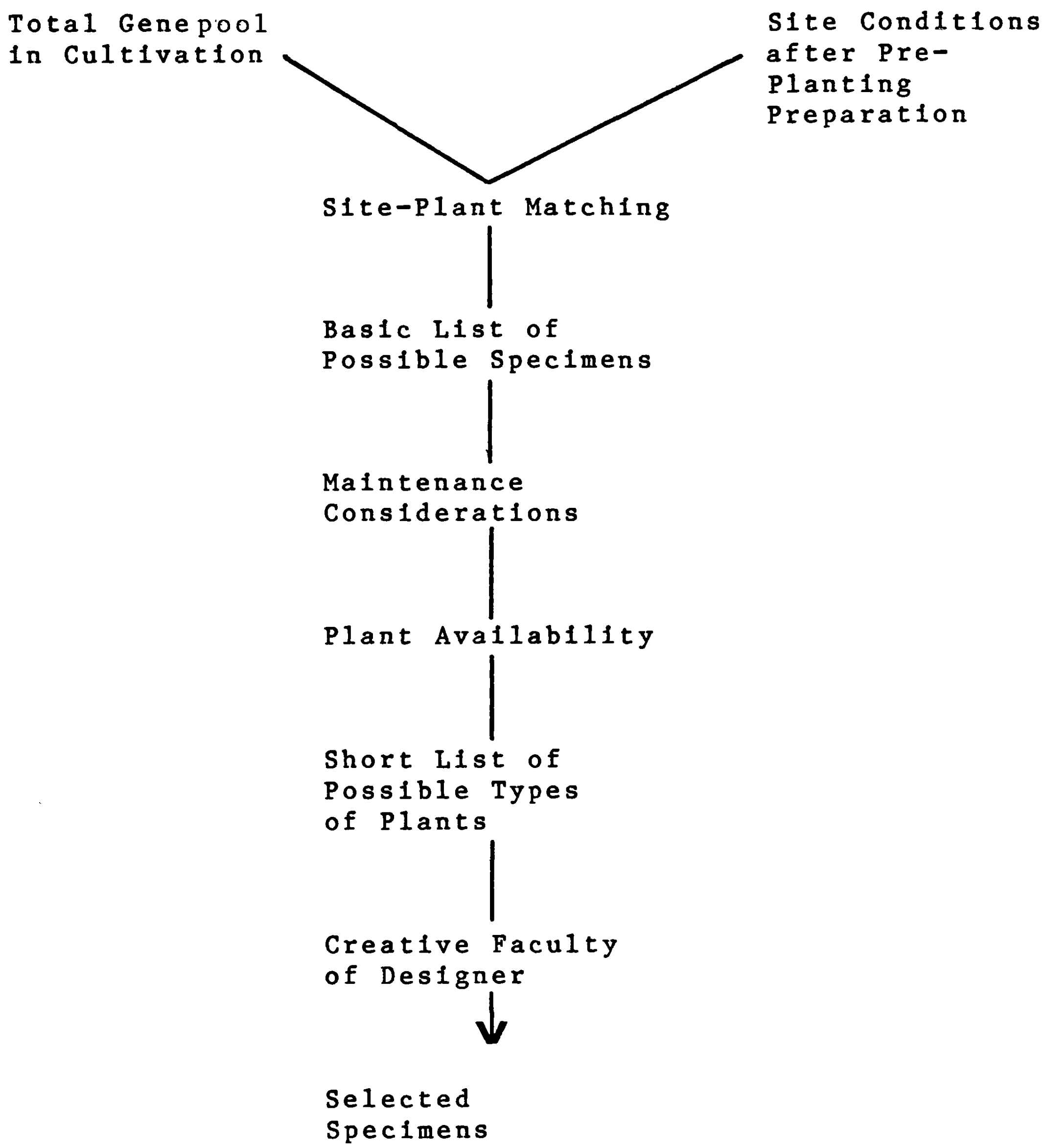
3.1.2 Influences on Plant Usage

It is clear that many apparently desirable species are not often used. In practice plant usage is based not on a thorough assessment of all the plants in cultivation, but on a small set of taxa which are both available, and acceptable in the light of contemporary fashion. This is typically the case when the selector has a restricted knowledge of decorative plants.

All fashion is fickle and plant selection is no exception but typically subjects chosen for planting in public open space must flourish with little or no assistance from cultivation whilst at the same time contribute to the contemporary design genre. Within such, often ephemeral, aesthetic concepts there has often been a strong biological basis to plant selection for example the pollution and shade tolerance of victorian urban plantings of *Aucuba japonica*. Indeed in the absence of such fundamental site tolerance it is unwise to allow fashion to influence plant selection as is evidenced by the many failed public plantings of Rhododendron cultivars in the last fifty years. By the same token the much discussed plantsmans concept of a quality plant has to be similarly modified to include only those capable of harsh site tolerance.

Fashion also provides us with numerous cases where a plant has been favoured simply as a result of its seasonal display for example the flowering of Malus and Prunus cultivars. To this praise for display may be added even less tangible concepts such as rarity and novelty.

Fig 3.1 The Plant Selection Process



The difference between whole plant, year round performance and seasonal display is nicely illustrated by the Royal Horticultural Societies criteria for The Award of Merit in contrast to the requirements that must be met for the Award of Garden Merit. Regretably there is no Award of Landscape Merit.

There is clear evidence that many good garden plants are only successfully transferred into landscape plantings if either their design role or their husbandry is changed for example Viburnum davidii moves from a single specimen plant to a ground cover subject and Rubus cockburnianus is no longer stooled annually but allowed to develop into an aggressive thicket of considerable value. This process of re-evaluation has always taken place but it appears to have accelerated in the past 25 years as evidenced by the excessive use of such low structure plants as the ubiquitous Cotoneasters. Regretably Britain has contributed little to either the selection or the landscape management of the taxa now in vogue. In spite of the richness of our decorative flora most of this work has been acheived on the mainland of Europe.

The factor that could ultimately determine the discrepancy between the range of plants used in landscape design and the total in cultivation is their availability from the nursery stock industry. It must be recognised that nurserymen can only reap the benefit of economies of scale by growing more specimens of fewer taxa rather than continuing the traditional British attitude whereby the quality of a nursery was judged on the length of its stock list. It is to be hoped however that specialist growers will help ensure that this trend does not result in the obliteration of our decorative plant heritage. Even if nurserymen continue to reduce the range offered their stock list should not be static, new types should replace less desirable ones in response to changes in landscape design or through the introduction of improved taxa.

3.2 Performance of Decorative Plants Under Cultivation in Britain

The concept of cultivated plant performance is concerned with the growth and appearance of a plant or group of plants of a particular taxon in a particular location hence it is the evaluation of the quality of a plants phenotype when growing under particular environmental conditions and judged by certain practical and aesthetic criteria. These ideas are central to the development of an information system such as Hortbase whose selection system is based on the concept that the quality of a plants phenotype in the landscape is profoundly influenced by the environment in which it is growing.

The major components of decorative plant performance, together with an appraisal of their contemporary importance are summarised in Table 3.2. Each component can be considered to range from a minimum (frequently unacceptable) value to a level considered to be the maximum attainable (the expression of the physiological optimum). The lowest level of acceptability for either the total plant or its components parts must remain an individuals choice; in some cases the suboptimal phenotype may be desired.

Nonetheless, for most cultivated plants there exists a general consensus of opinion of what acceptable performance is, although this is generally a value judgement influenced by local experience and meaningless outside that location. This is commonly the case when performance is governed by climatic as opposed to the more readily standardised environmental factors such as substrate characteristics.

For example, in Southern England, Camellia japonica flowers satisfactorily in full shade whereas in Northern England full sun is essential to elicit the same response. To be meaningful a description of the performance of this plant must document such characteristics. These types of responses have been described for a number of species and demonstrate the need for a plant orientated classification of climate.

Despite the highly subjective nature of acceptable plant performance in the landscape contemporary European design

Table 3.2 Some Components of Cultivated Woody Plant Performance

Decreasing importance --->
(under typical urban landscape conditions)

Vegetative Growth				
Root Systems	Aerial Parts	Stem and Bark Characteristics		
* Rate of establishment	* Overall form	* Intensity of display	* form	
* Tolerance of difficult soils	* Vigour	* Persistence	* chronology	
	* Leaf quality			
		Seasonal Leaf Characteristics		
		* Intensity of display	* form	
		* Persistence	* chronology	
Reproductive Growth		Flower Characteristics		
		* Intensity of display	* form	
		* Persistence	* chronology	
		Fruit Characteristic		
		* Intensity of display	* form	* viable seed
		* Persistance	* chronology	

typically links it with a vigorous almost lush condition.

"Fall off" of performance as a result of environmental unsuitability may take the form of a uniform depression in the quality of expression of many attributes. This usually happens when hostile substrates or weed competition are encountered. Alternatively there may be a hierarchical sequence by which certain plant processes are sequentially jettisoned, whilst others appear relatively unaffected. This sequence may manifest itself by such acts as flower bud abortion or premature leaf fall.

Selective fall off in performance has been suggested as the explanation as to why specimens of Betula pendula and Alnus incana found colonising sites such as mine spoil heaps have,at least in the short term, seemingly lost their ability to reproduce (Last 1977).

Sequential jettisoning is most obvious however in the flowering and fruiting of plants in response to both regional and localised variations in the temperature and radiation climate of Britain.

Indeed whilst the predominantly oceanic British climate is ideal for the vegetative growth of many species it is not necessarily ideal in terms of carbohydrate accumulation for the actuation of the more senstive phases of the life cycle such as flowering and fruiting (Forest Comm. 1957).

Many continental species experience much higher air temperatures and solar radiation regimes in their natural habitats than Britain can provide. With such species the growing season climate may be marginal for some or all of the developmental processes. Mapping decorative plant performance in the field along altitudinal and latitudinal transects of Britain would confirm these relationships. Some landscape or potential landscape plants are therefore bound to perform badly in parts of the British Isles and cannot be improved by cultivation as discussed in 2.1.3.

Similar responses are attributed to some native species at the margins of their British distribution for example, Nardus strictus (Pearsall 1965) in response to altitude and Tilia cordata (Piggott & Huntley 1978) in response to increasing latitude. In both these cases the suppression of reproductive capacity occurs as a result of a relatively small reduction of solar radiation and air temperature. The much larger localised variations such as occur in radiation climate as a result of shading produce correspondingly more dramatic responses, as has been demonstrated by Jackson and Palmer (1977a,b) with regard to flower and fruit set in Apples. These responses reflect the requirements of the physiological processes which control the level of plant performance, and are discussed further in the sections dealing with Climatebase and Plantbase.

4. The Study of Decorative Plants

4.1 Sources of Information and Their Impact Upon Plant Selection and Use

In order to achieve the effect envisaged during the design stage it is necessary for the professional user of plant material to be aware of both the biological and aesthetic capabilities of plants and how these can be modified by environment and cultivation. Traditionally this understanding has, in the main, been attained by reference to the following sources of information:

a) the botanical and horticultural literature

b) the observations of plantsman

c) public and institutional reference collections

d) domestic gardens

e) herbaria

a) The Botanical and Horticultural Literature

As a distillation of aquired wisdom the literature has been, and remains the most potent source of information on decorative plants.

The literature on decorative plants is extensive in coverage and in some cases authoritative, but from the viewpoint of the landscape professions much of it suffers from the following deficiencies:

i It is aimed at the amateur gardener rather than the professional practitioner of landscape and the plant responses it records are those attained under the favourable conditions of the garden. It therefore needs interpretation before being applied outside that location.

ii Information of interest to contemporary landscape practitioners such as tolerance of residual herbicides, compacted soils, and coppice renewal, are rarely mentioned.

iii A clear separation between the needs of "landscape" and traditional decorative horticulture as represented by amateur gardening and some local authority horticulture, has become increasingly obvious in Britain during the past decade. In spite of this few if any authoritative works on the characteristics of decorative plants have been published to serve this new user group, although in North America a few examples can be identified (Dirr 1977).

iv It is primarily taxon indexed, therefore knowledge of plant names is a pre-requisite to obtaining information. This is a serious handicap to those who are not specialists in decorative plant studies, and frustrates the designer who is selecting primarily to realise a design concept in terms of size, shape, colour, and seasonality.

v Typically the literature is inconsistent in the presentation of data, information on specific topics being randomly omitted or included. Many of the books are designed to be read as a work of literature rather than referred to for specific technical points. Indeed such a use is often frustrated by poor referencing and indexing. The exceptions to this trend are floras and identification manuals such as Mitchell (1974, 1975)

v The literature only achieves satisfactory coverage of decorative plant characteristics when viewed as a whole, i.e it is necessary but extremely difficult to exhaustively cross reference between many sources. For the professional practitioner this may often prove impractical in terms of time, money, and most important the availability of the literature.

b. The Plantsman

Britains tradition of producing large numbers of "plantsmen" i.e individuals who desire to cultivate, observe and accumulate knowledge of decorative plants is possibly unique.

In many ways the plantsmans attitude is similar to that found in the authoritative literature, indeed much of the latter has originated from the writings of this group.

Historically such individuals have had a great influence upon the selection and usage of decorative plants in British landscapes, although given the now established divergence of contemporary landscape from traditional decorative horticulture, few of this genre are in future likely to be involved to any extent in providing information on the planting of public open space. Plantsmen have always been relatively rare amongst the ranks of landscape designers and managers and it is unlikely that this trend can be reversed. Plantsmen who are not professionally involved in landscape are unlikely to be interested in appraising plants for such sites and some may even be contemptuous of design philosophies which aim to submerge individual plant specimens into landscape vegetation.

c) The Reference Collections

Although British reference collections have acted as the source for the observations upon which the literature is largely based, unlike their equivalents in other western nations and especially the United States, there are few precedents of centrally funded institutional collections acting as providers of information on subjects of contemporary landscape interest.

Unfortunately such collections have failed to develop their role beyond that of traditional academic taxonomic research or providing the public with a pleasant garden experience. The potential of living collections as sites for research into subjects such as nutrient requirements, spacing experiments or even basic evaluation trials has not generally been recognised by these institutions, perhaps as a result of the schism that has often existed between scientific and garden management staff (Wellavize 1978). In practice all Britains decorative plant collections, state and privately owned are primarily garden as opposed to landscape orientated, and have largely resisted the opportunity to evaluate existing or experiment with "new" husbandry practices.

All the sources of information discussed in this section have one thing in common; typically they evaluate the performance of a plant as a garden subject. One might speculate that some of the cumulative long term consequences of this for British public open space and institutional landscape, have been as follows:

i The retardation of the widespread adoption of non gardenesque landscape styles, appropriate in scale , composition and function to contemporary society

ii Techniques of vegetation management based on an understanding of plant physiology have been disregarded.

iii The lack of imaginative plant evaluation within reference collections has meant that the potential of currently obscure but useful plants remains untapped.

Information from sources outside traditonal decorative horticulture is now beginning to have an impact and even reverse some of these undesirable trends (Grime 1979, Bradshaw & Chadwick 1980, Greenwood & Moffat 1982)

The author believes that a computer based informatiom retrieval system, based on the appraisal of decorative plant data from a landscape perspective, can help to rectify some of the shortcomings of traditional information sources.

4.2 Computer Based Information Systems in Decorative Plant Studies

To date, within the field of decorative plant studies the impact of computer information and retrieval (databases) has largely been confined to botanical inventories. (Hunt 1978, Morris 1980) In related disciplines such as forestry and agriculture, several databases have been developed although these have largely been concerned with the storage and retrieval of bibliographical data rather than information on plant characteristics (Yerke 1978, Magill 1980)

A database that does record information on plant characteristics is the Plant Information Network (PIN) developed at Colorado State University (Vories, Bryant, Bonham, & Dittenberner 1978). This is a large database (in excess of 4,000 records) the purpose of which is to store and supply information on the vascular plants native to and naturalised in the States of Colorado, Montana and Wyoming.

Currently there is increasing interest in the computerisation of cultivated plant data. Landscape architecture and plant retailing are two fields that have recently come to recognise the potential of computers, and both "in house" and commercial packages are now being developed. (Conradi 1982). Whilst these might be seen as positive developments,in view of the comments made in 4.1, it is perhaps appropriate to express concern at the "quality" of information that such systems are likely to contain.

Relative to other areas of technology and commerce developments such as these have been slow, because many practitioners have not recognised the deficiencies of the existing sources of information.

The following are some of the inherent advantages of computerised information retrieval over traditional means of information gathering:

a) The databases which constitute computer information retrieval systems are essentially tables of data, and thus by their very nature encourage the database manager to quantify data for inclusion. This quantification often demands a critical reappraisal of existing data, as has been the case with Hortbase.

b) Unlike the text book which rapidly becomes outdated unless new editions are published, the computer based system need not suffer from this limitation due to the ease with which component data can be deleted and updated.

c) The ease with which new data can be appended, (compared to writing or rewriting a book) facilitates the recording of the observations of many individuals and institutions which might otherwise be lost.

d) The amount of information contained within any "system" is potentially enormous, without being counterproductive, i.e it does not overwhelm the user who is only confronted with the data requested, and not the total the system actually contains. At the same time, in contrast to the imperfect recall of the human memory the computers response to a selection request is always from the full set of stored data.

e) Speed; information is available almost immediately and requires little of the effort associated with a conventional literature search. The latter is of importance where the user has not been trained to accept the rigours associated with the aquisition of knowledge.

f) Within limits of performance defined by the structure of the database, the capacity to cross reference between component topics is unlimited, i.e information can be retrieved in response to any combination of request parameters. This "key word out of context", as opposed to the taxon orientated indexing of literature facilitates the logical non biased selection of genotypes by non plantsman.

Before proceeding further the term database needs to be defined.

In essence all (relational) databases consist of a central core of data from which information can be retrieved in response to selection requests, activating system programmes.

The data is stored in the form of a large or very large table, consisting in turn of rows and columns of data. A row or line of data corresponds to one record. Table 4.1 illustrates a very simple database consisting of 5 records each consisting of 5 attributes or topic headings.

Table 4.1 Schematic Representation of a Simple Database

plant name	type	height(cm)	width(cm)	origin
Acer davidii	tree	1000	600	China
Acer griseum	tree	1000	600	China
Acer palmatum	tree	1000	600	Japan
Acer platanoides	tree	2000	2000	Europe
Acer rubrum	tree	2000	1500	America

The data in a database table must conform exactly to a format previously defined in a structure or domain statement.

For example with reference to Table 4.1 it can be seen that the first piece of information must be a botanical name followed by type, height, width, and country of origin. The allowed length of each topic of information or field in terms of numerals or letters is also defined in the domain statement. Table 4.2 is an example of part of the domain statement of Plantbase.

Table 4.2 The Domain Statement of Plantbase

```
domain:
snum                          fixed dec(5),
name                          char(48),
height                        fixed dec(4),
width                         fixed dec(4),
height_10                     fixed dec(4),
width_10                      fixed dec(4),
form                          fixed dec(2),
relation: plant (snum name height width height_10
width_10 form)
```

The database table may be further structured by "lumping" together attributes into sub divisions known as relations.

Relations are generally used to sub divide databases containing large amounts of unrelated data into sub sets of related data in order to increase the efficiency of the information retrieval process. For example, the database table in Table 4.1 might be split into two relations, one containing name, height and width, the other containing name, type and country of origin. Name would be used in both relations as it represents the key identifier, without which retrieved data is meaningless.

In most database systems, data is retrieved from the table by constructing a "retrieval statement" which defines the selection parameters. The retrieval statement activates the systems in house programmes by which data is located in a specified table, abstracted, and displayed via a VDU screen or printout.

Conceptually, the process is analogous to a person (the computer) scanning through a telephone directory (the database) consisting of rows and columns of data for a subscribers name (the selection parameter), which in turn identifies the line containing the telephone number (the data to be retrieved).

In terms of computer based information retrieval the selection algorithm for this process might be described as:

```
select number
from telephone directory
where name = John Smith
```

5. The Development of Hortbase

The preceeding chapters have reviewed some of the factors that determine both the range and success of the decorative taxa employed in landscape. The path to an information system that might take these factors into account has not been straight forward. This has been due to the combination of a dearth of information in certain fields, and the conflicting viewpoints of potential users.

For example, the comparative richness of the British decorative flora has been stressed, and early in the project a list of 3,500 species and cultivars were identified and shortlisted for inclusion in Hortbase. However, some potential users have expressed the opinion that such a system was of limited use unless it contained the total complement of decorative plants in cultivation (Sales 1980). Others felt 3,500 was an excessive number and ran counter to the spirit of plant rationalisation moves within the landscape industries. (Notcutt 1981).

Within the overall objective of providing information which allows the practitioner to select potentially successful phenotypes for the landscape of institutions and public open space, Hortbase has attempted to accommodate as diverse a range of views as possible.

The vehicle on which the system has been developed to its present format is a Honeywell Level 68 DP 5-2 main frame computer with twin processor and cache memory. The operating software is Honeywell Multics, a time sharing interactive system with absentee mode facility (Honeywell 1978). The systems database creation and management software is described in 5.1

Hortbase consists of two databases, these being Plantbase and Climatebase which contain 113 and 39 attributes respectively. Plantbase currently contains information for over 200 genotypes (see Table 5.1) and Climatebase provides information on the key climatic limitations to plant growth and development in any location on the mainland of England and Wales.

Table 5.1 Genotypes Currently Listed on Plantbase

Acer campestre
" cappadocicum
" platanoides
" pseudoplatanus
Aesculus hippocastanum
Alnus cordata
" glutinosa
" incana
Amelanchier lamarkii
Azara microphylla
Berberis x aggregata
" gagnepainii
" x stenophylla
" thunbergii
" t.'Atropurpurea'
" verruculosa

Berberis wilsonae

Betula jaquemontii

" pendula

" p.'Dalecarlica'

" p.'Tristis'

Buddleia davidii

Camellia x williamsii 'Donation'

Carpinus betulus

" b.'Fastigiata'

Ceanothus 'Cascade'

Cedrus atlantica 'Glauca'

" deodara

Celastrus orbiculatus

Chaenomeles x superba 'Crimson & Gold'

Clematis armandii

" montana rubens

" orientalis L&S form

" viticella

Cornus alba

" a.'Elegantisissima'

" a.'Spaethii'

" stolonifera 'Flaviramea'

Cotinus cogygria 'Royal Purple'

Cotoneaster conspicuous 'Decorus'

" 'Cornubia'

" dammeri

" franchetii sternianus

" horizontalis

" microphyllus

Cotoneaster salicifolius 'Autumn Fire'

" salicifolius flocossus

" salicifolius 'Gnom'

" 'Skogholm'

Crataegus x lavallei

" prunifolia

" monogyna

Cytisus x praecox

Elaeagnus x ebbingei

" pungens 'Maculata'

Erica x darleyensis

Eucalyptus gunnii

" niphophila

Euonymus europaeus

" e.'Red Cascade'

" fortunei 'Darts Blanket'

Fagus sylvatica

" s.'Dawyk'

" s.'Pendula'

Fatsia japonica

Forsythia 'Lynwood'

Fraxinus excelsior

" oxycarpa 'Raywood'

Garrya elliptica

Genista aetnensis

Ginkgo biloba

Griselinia littoralis

Hedera canariensis 'Gloire de Marengo'

" colchica 'Dentata'

Hedera c. 'Paddys Pride'

" helix 'Hibernica'

" h.'Ivalace'

Helianthemum 'Wisley Pink'

Hippophae rhamnoides

Hydrangea petiolaris

Hypericum calycinum

" 'Hidcote'

Ilex x altaclarensis 'Camellifolia'

" aquifolium

Jasminum officinale

" nudiflorum

Juniperus communis 'Repanda'

" horizontalis 'Hughes'

" 'Pfitzeriana'

" 'Hetzii'

Kerria japonica

Laburnum 'Vossii'

Larix x eurolepis

Lavandula 'Hidcote'

Lonicera periclymenum 'Serotina'

" x tellemaniana

" pileata

Mahonia 'Charity'

" japonica

Malus floribunda

" hupehensis

" 'John Downie'

" tschonskii

Osmanthus 'Burkwoodii'

Pachysandra terminalis

Parthenocissus henryana

" quinquefolia

" tricuspidata

Phormium tenax

Picea omorika

Pinus mugo

" nigra var nigra

" radiata

" sylvestris

Platanus x acerifolia

Polygonum baldschuanicum

Populus alba

Potentilla 'Elizabeth'

Prunus avium

" laurocerasus

" l. 'Otto Luyken'

" lusitanica

" sargentii

" serrula

" spinosa

" 'Tai Haku'

Pyracantha atlantoides

" 'Orange Glow'

Quercus coccinea 'Splendens'

" ilex

" robur

" rubra

Rhus glabra 'Laciniata'

" typhina

Ribes sanguineum 'Pulborough Scarlet'

" speciosum

Robinia pseudoacacia

" p.'Frisia'

Rosa 'Canary Bird'

" eglanteria

" 'Macrantha'

" 'Max Graf'

" moyesii 'Geranium'

" 'Nevada'

" 'Penelope'

" 'Raubritter'

" rubrifolia

" rugosa

" 'Scarlet Fire'

Rosmarinus officinalis

Rubus cockburnianus

" tricolor

" tridel 'Benenden'

Salix alba 'Chermesina'

" a. 'Sericea'

" elaeagnos

" hastata 'Wehrhahnii'

" matsudana 'Tortuosa'

" pentandra

Salvia officinalis

Sambucus nigra

Sambucus racemosa 'Plumosa Aurea'

Sarcococca hookerana digyna

Senecio 'Sunshine'

Skimmia japonica 'Foremannii'

Sorbaria arborea

Sorbus aria

" a. 'Majestica'

" aucuparia

" cashmiriana

" 'Embley'

" hupehensis

" 'Joseph Rock'

" sargentiana

" scalaris

" thuringiaca 'Fastigiata'

Spartium junceum

Spiraea 'Arguta'

" 'Snowmound'

Stephanandra incisa 'Crispa'

" tanakae

Stranvaesia davidiana

Symphoricarpos albus laevigatus

" 'Hancock'

Syringa microphylla 'Superba'

" swegiflexa 'Fountain'

Tamarix ramosissima 'Rubra'

Taxus baccata

" b. 'Repandens'

Taxodium distichum

Tilia cordata

" petiolaris

Ulex europaeus

Viburnum betulifolium

" x bodnantense 'Dawn'

" davidii

" lantana

" opulus

" plicatum 'Mariesii'

" rhytidophyllum

" tinus

Vinca minor 'Bowles Variety'

Vitis 'Brant'

" coignetiae

Wisteria sinensis

Yucca filamentosa

" gloriosa

Both Plantbase and Climatebase are composed of only one relation which creates difficulties in file creation and editing prior to data storage. This is due to the length of each record, which in Plantbase consists of over 400 characters. During the projects life various relation formats have been experimented with, although none have proved as satisfactory overall as the single relation. This is because the structure of databases often represents a compromise between the needs of the database manager and those of the user, and whilst splitting databases into relations eases the problems of the former it frequently hampers the ease with which data is retrieved.

The constituents of Hortbase i.e Plantbase and Climatebase have been retained as separate entities as they are not logically related, that is, the climatic data of Climatebase relates to geographical location (i.e a location is the key identifier), whereas Plantbases key identifier relates to a specific taxon.

The form in which an attribute or topic heading is to be represented in a record is defined in the domain statement, the options being as follows:

Words or phrases	e.g	red or good or high or <u>Acer</u> <u>platanoides</u>
Numerals	e.g	1, 2, 3, ... n
Letters	e.g	a, b, c, ... z

Words have the great advantage of being much more meaningful or "user friendly" , compared with the latter two options. The limitations on the exclusive use of words are as follows:

a) Ultimate size of the database. To use words throughout Plantbase, the data storage requirements would be increased by a factor of 5 or more.

b) Ease of usage. Words create problems for both the database manager and the user with regard to amount of typing necessary.
For example, if the attribute value for a plants overall leaf texture was recorded as words rather than as a single character, when storing or retrieving data it would be necessary to type:-

compact - feathery

as opposed to

f

As a result words have only been used in data fields where they are essential or most valuable, i.e Name, User Limitations, and Additional Features.

Numerals have been used where a relationship exists between the range of attribute options, e.g for an attribute dealing with the intensity of display of a part of the plant, the options might be, low, average, high, outstanding, and these correspond satisfactorily to the number sequence 1, 2, 3, 4. The use of number sequences also allow for relational operators e.g <= >= to be used to sophisticate the selection process.

Numerals have therefore been used extensively throughout Hortbase, wherever these relationships exist.

Letters represent probably the least useful option for attribute values, as they are neither "user friendly" nor do they infer a mathematical relationship. In Hortbase they are confined to the attributes where they give some indication of the word they represent.

For example, the following letter code is used to describe leaf surface texture on Plantbase :

The options are:

	Code Letter Used
rough (e.g prominent venation)	r
smooth	s
hairy	h

With attributes where there are many options, e.g plant leaf texture, a letter based system tends to break down due to the need to use the same letter twice, for example spiky and smooth.
The consequences of the choice of attribute values are considered in the Discussion.

5.1 Information Storage and Retrieval with Hortbase

New lines of information (records) are appended to the database table by using the Linus (Logical inquiry and update system) capacity of Multics (Honeywell 1979a). This involves issuing a store request to operate upon a segment containing lines of data. A segment is an addressed unit of disk storage within the computers memory.

Data may be stored one line at a time or as hundreds of lines, the latter being known as file storage. All these processes are carried out interactively at a terminal and do not require intermediary systems such as punch cards. Although file storage allows the data base manager to store large numbers of records very quickly, the bottle neck in the process is represented by the time it takes to populate (i.e type) and edit the files prior to actual storage.

When retrieving information the user decides which database he wishes to interrogate, ready's the chosen database for retrieval, and then enters Linus, an in house database management system. The information to be retrieved is specified by Lila (Linus language), a high level non-procedural language, which allows the selection algorithm to be specified in the form of a select, from where block.

The select clause selects attribute values, from tables (relations) where rows of the table satisfy the specified

conditions (the selection parameters). The syntax of Hortbase retrieval statements is as follows:
(for clarity each line is considered individually)

Select Line

May contain one or more attribute name each separated by a blank space, except in the case of Climatebase where attribute names and related microclimatic adjustment attributes are separated by addition signs which inform the computer that the attribute values are to be totalled. For an example see 5.1.1

From Line

Only one relation may be used in any retrieval statement i.e either climate or plant.

Where Line

This may contain one or more attribute names, separated from the next by a relational operator, followed by an attribute value and finally a logical operator.

Allowable relational operators are:

greater than
less than
greater than or equal to
less than or equal to
equal to
not equal to

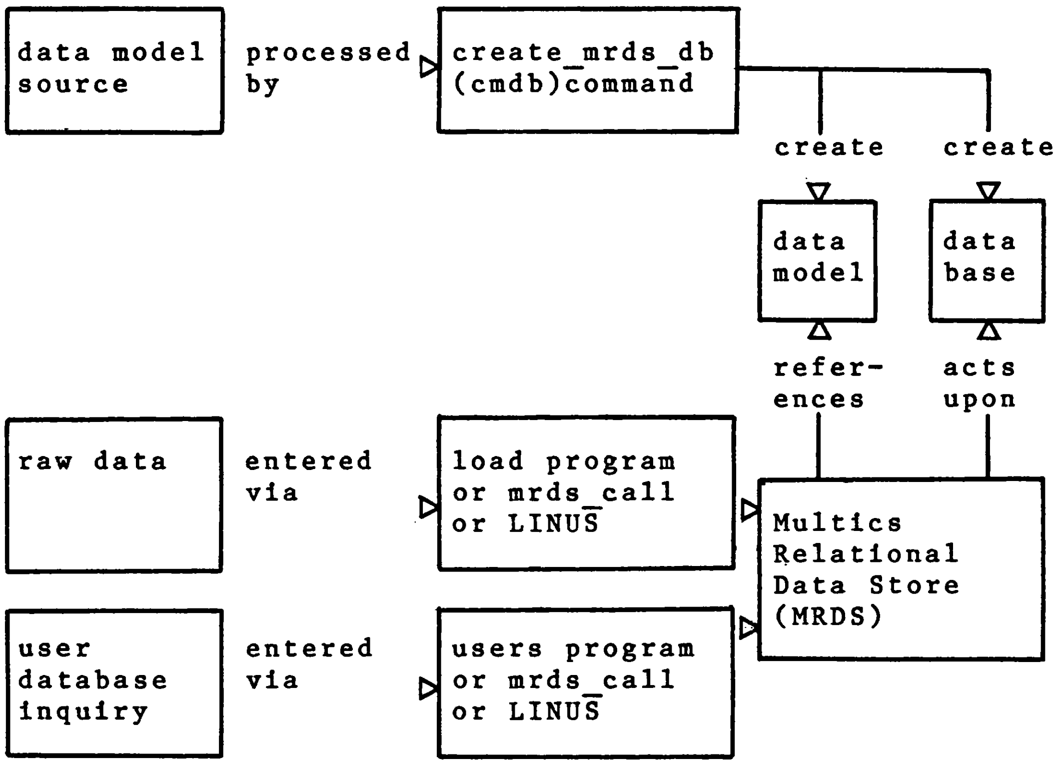
Allowable logical operators are:

and
or
not

The process of data model and database creation,information storage,and retrieval with Multics, are illustrated in Fig.5.1.

Fig. 5.1 Format of a Honeywell Multics Datastore System

(Honeywell 1979b)



5.1.1 Retrieving Information with Hortbase

a) Climatebase

A simple enquiry statement might be constructed as follows:

select	average winter cold rating for
	75-150m solar radiation for 0-75m
from	climatebase
where	climatic reference area = 35

This request would result in the computer producing a value of 10 for average winter cold (drawn from the 1-14 scale by which this assessed on Climatebase) and 3 for solar radiation (drawn from a 1-4 scale) for the specified altitude (75-150 m) for a planting site in climatic reference area 35.

A slightly more complex retrieval statement might be:

select	average winter cold 75-150m + valley bottom adjustment solar radiation 75-150m + west wall adjustment
from	climatebase
where	climatic area = 35

This request now contains microclimatic adjustment factors by which the computer corrects its initial prognosis in the light of the more detailed description of the site. For example the corrected winter cold rating would be reduced to 8 (2 zones colder) whilst the radiation rating would be corrected to 4 (1 zone higher). Any combination of the 39 attributes contained within Climatebase may be used in either or both the "select" or the "where" line, i.e in addition to above approach the user can, should he wish use the database to locate the geographical area where the specified climatic conditions prevail.

b) Plantbase

A simple enquiry statement might be as follows:

select	name height at maturity width at maturity
from	plantbase
where	growth rate woody = very fast and tolerance of simazine applied immediately after planting = high

In response to this request the computer will print the name, height at maturity in centimetres, width at maturity in centimetres for any plant which is tolerant of simazine applied immediately after planting at a specified rate and is very fast growing. Any combination of Plantbases 113 attributes may be used in either the "select" or and the "where" line.

A more complex retrieval statement which introduces selection parameters derived from a previous interrogation of Climatebase might be:

select	name height at maturity width at maturity height at 10 years width at 10 years aesthetic life span user limitations
from	plantbase
where	hardiness = 8 and can flower satisfactorily in half shade in solar radiation zone 4 and growth rate woody = fast and tolerance of simazine applied immediately after planting = high

As in the previous example the computer will print all the available data for topics in the "select" line for any plant which is very fast growing, tolerant of simazine applied immediately after planting, is hardy in winter cold zone 8 and can flower satisfactorily in half shade in radiation zone 4 (e.g a site at 75-150 m in reference zone 35)

For clarity all these examples represent longhand versions of actual Hortbase requests.

The following is the latter request using the language of Hortbase.

```
select        name height width height_10 width_10
              aesth_life user_lim
from          plantbase
where         hardiness = 8 + flower_sun-inter = 4
              growth_woody = 4 +  herb_pre_est_sim
              = 3
```

These latter examples are important in that they demonstrate the function of Climatebase as a first level of selection, evaluating the planting site in terms of climatic factors that may ultimately limit success.

6. The Development of Climatebase

As discussed in 3.2, many decorative plants do not perform satisfactorily throughout the British Isles. These unsatisfactory phenotypic responses can frequently be related to the nature of the climate (micro and macro).

In order that Hortbase might achieve its objectives it was essential to develop a means of quantifying plant response to climatic phenomena. Quantification was necessary not only for obvious interelations such as tolerance of low winter temperatures but also for more subtle interactions such as the effect of localised shading within the overall insolation regime upon the vegetative and reproductive phenotype. In contrast to decorative plant users, crop producers have striven to define precisely, the climatic regime in which a crop can or cannot perform satisfactorily (Amerine & Winkler 1944, Bleasdale 1973). Similarly, ecologists have also recognised the importance of a classification of climate as an aid to understanding plant and animal behaviour (White & Lindley 1976, White 1979). Consideration of the following factors lends additional weight to the case for such a system:

a) Inadequacy of existing information on the response of plants to climate

The only aspect of climatic interactions normally discussed in the decorative plant literature are plant response to low winter temperatures, and even then this is often in only vague terms for example, "not hardy in the north", "hardy in the south west".

Response to growing season temperatures, solar radiation, and soil moisture deficits are rarely if ever documented. Even when concepts such as hardiness are discussed there is frequently ambiguity over what this term actually means. At its broadest hardiness may in some cases be used to describe the response of both physiologically dormant and actively growing plants to sub zero temperatures, or even tolerance of environmental factors quite unrelated to climate.

There is no consensus in the literature where by a definitive concept of "hardiness" is employed in relation to winter minima. In addition the conditions under which a plant is ajudged to be "hardy" are rarely defined, e.g is hardiness assessed in the context of an average or a ten or twenty year extreme winter such as 1962-63. Finally there is considerable latitude amongst horticulturalists regarding the extent of damage a plant may sustain and still be considered hardy.

The absence of a clearly defined, standardised terminology perpetuates the confusion and commonly held misconceptions and acts as a barrier to understanding the relationships between decorative plant performance and climatic phenomena.

Much of the collective knowledge of decorative plant hardiness contained within the literature has been derived from the observations of amateur gardeners who have not attempted to identify causes, but merely record effects. Given the number and the complexity of interacting factors which determine plant hardiness it is not surprising that the subject of decorative plant hardiness is awarded an almost mystical reverence by some otherwise accurate and disciplined authors.

b) Characteristics of potential Hortbase users.

Many of the potential users of Hortbase are likely to be drawn from the ranks of the design professions, of whom only a few will possess the plantsmans knowledge of a taxons response to climate, for example the non plantsman is unlikely to be aware that *Liquidamber styraciflua* grows weakly in Northern England or that *Mahonia japonica* produces a far superior phenotype when grown in dense shade.

As it stands, Britains outstanding depth of meteorological data is of little value to this group, unless it is first linked to the actual responses of plants, a task that many designers are ill equipped to undertake. Almost inevitably non specialists must remain frustrated by the confusing and often contradictory literature associated with decorative plant response to climate. In the light of this, literature which offers confident, but inevitably rather simplistic pronouncements such as Hilliers Manual of Trees and Shrubs (1974), is generally a source of reassurance for many practitioners.

6.1 Climatic Zonation of Britain for Decorative Plants

Previous classifications of the British climate in relation to plant growth and performance have primarily been developed with the needs of agriculture, forestry and silviculture in mind (Thornethwaite 1948, Anderson & Fairburn 1955, Fairburn 1968).

To the authors knowledge their have been no serious attempt to develop comparable classifications aimed specifically at the growth and performance of decorative plants in the British landscape.

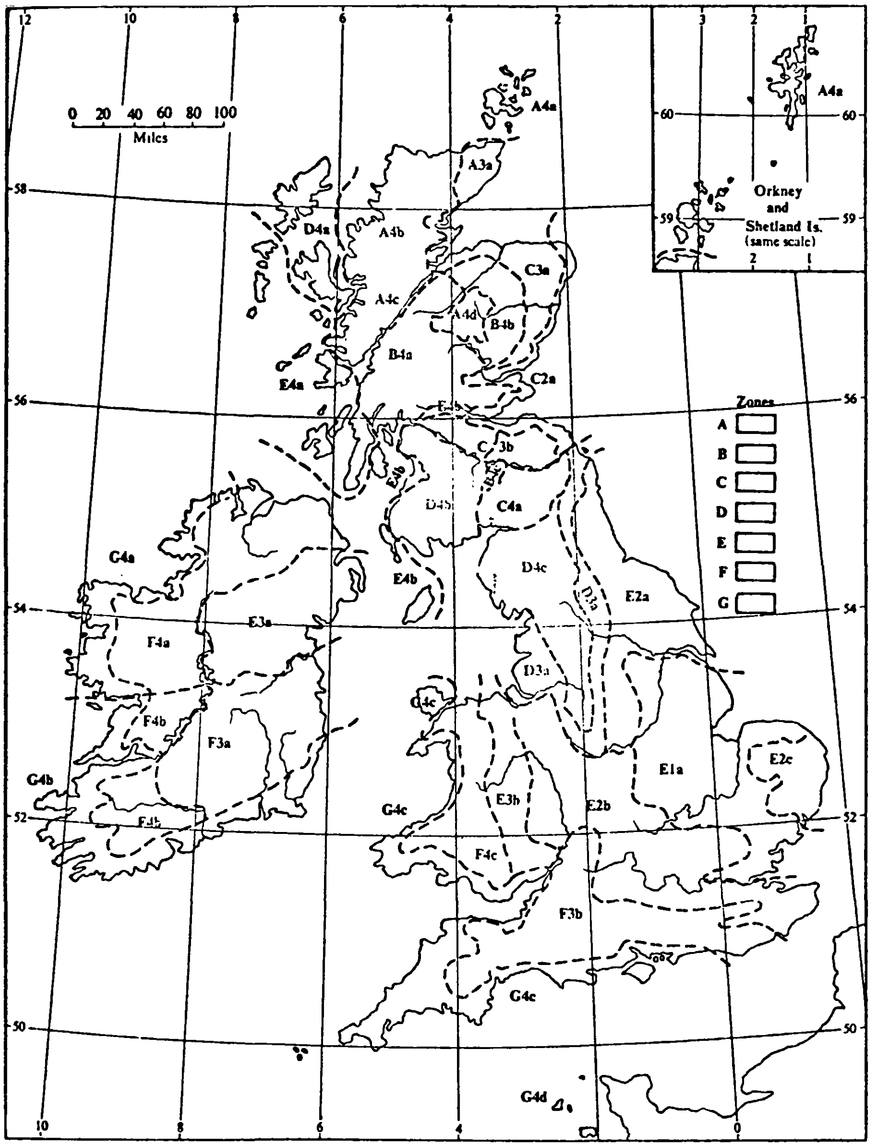
In the U.S.A several decorative plant orientated classifications have been developed (Rehder 1951, Dirr 1977), although given that they do not take into account altitude or indeed any localised, modifying influences upon average annual minimum temperatures, they cannot be considered as more than very general guides.

To date perhaps the most useful climatic zonation of Britain for decorative vegetation is that of Fairburn (1968) which is based upon the integration of the number of growing season days warmer than 6 degrees centigrade with precipitation.

From the viewpoint of landscape practitioners, this classification suffers from several deficiencies. Although plant orientated it is primarily a general climatic classification. The response of cultivated taxa in terms of the minimum zones for acceptable performance are not integrated with the classification.

Fig 6.1 Climatic Classification of Britain using the Parameters of Growing Season Warmth and Precipitation

(data from Fairburn 1968)



The Figure illustrates a climatic classification created by superimposing 4 zones of rainfall onto 7 zones of temperature (based upon the length of the growing season) reduced to sea level.

The system assesses the characteristics of the growing season only, and as a forestry orientated model it assumes cold hardiness will not be an important issue and therfore does not include a classification of winter minima.

Due to the cartological presentation of the data the model can only represent the climate as it is found at a given altitude, in this case sea level. This is an inherent weakness of all graphical approaches. Such classification cannot recognise the localised, but often critical effects of microclimate. It is in other words an areal as opposed to location orientated classification. Given the importance of topographically generated microclimates , horizontal climatic models which do not take altitude in to account are often relatively meaningless (Forest Commission 1957). By using the parameter of number of growing season days warmer than 6 degrees centigrade to represent temperature, it is difficult to infer the levels of warmth actually experienced, e.g in the model under discussion, the West Midlands and coastal Northumberland are in the same zone, despite considerable differences in growing season temperatures in terms of monthly means. For example, for Shipston on Stour (Warwickshire) the monthly mean for the period April to September = 14 degrees centigrade, whilst for Cockle Park, Northumberland the corresponding figure is 12 degrees (Met.Office 1976). As a result this model gives little indication of the suitability of given area to facilitate temperature sensitive developmental processes such as flowering and fruiting.

Fairburns classification defines suitability for vegetative growth and is of only limited value to those concerned with the reproductive phases of plant growth. In the light of these criticisms it was decided that Climatebase must be developed to attempt to :

a) Identify and incorporate both macro and micro climatic parameters that are relevant to decorative plant performance in Britain.

b) Be capable of predicting values for these parameters for any location, irrespective of altitude and relate these to the performance of decorative taxa in terms of the minimum values necessary to produce and sustain a satisfactory specimen. These values must be definitive and not require further interpretation by the user of the system.

A cartological or graphical approach inevitably imposes restrictions upon satisfying these requirements. If however the medium of the database is substituted many of the difficulties cease to exist.

The climate of the planting site is a logical starting point from which to evaluate plants, however it was recognised that, with the exception of plant hardiness, many popular landscape plants, differential performance in response to climate was only perceivable when comparing planting sites which represent the climatic extremes found in England. For example the south west and north east. Unsatisfactory performance in these popular plants can generally be attributed to edaphic and environmental factors other than climatic. The identification of the genotypes of value to landscape which exhibit a sufficiently differential response to the spectrum of British climates was therefore the first step in the development of Climatebase.

6.2 Components and Structure of Climatbase

Climate is considered in five altitudinal ranges for the parameters listed in Table 6.1. These are; 0-75m, 75-150m, 150-225m, 225-300m, 300-375m. Areas of Britain above 375m altitude are sparsely populated and unlikely to be subject to extensive landscape planting.

Ideally Climatebase would cover all of Great Britain, unfortunately this has not been possible due to the scarcity of comparable climatic data for Scotland and Northern Ireland. As a result only the climate of England and Wales is documented in Climatebase.

Much of the meteorological data used in the development of Climatebase is derived from the MAFF Technical Bulletin 35, The Agricultural Climate of England and Wales (Smith1976b), which represents one of the most comprehensive colections of comparable meteorological data ever assembled.

Table 6.1 <u>Components of Climatebase</u>

Subject	Specific Subject Matter	Climatebase Name
	Reference Area	Area
Winter cold	Zonation of average winter cold at 0-75m	hardiness_av_0-75m
	Zonation of average winter cold at 75-150m	hardiness_av_75-150m
	Zonation of average winter cold at 150-225m	hardiness_av_150-225m
	Zonation of average winter cold at 225-300m	hardiness_av_225-300m
	Zonation of average winter cold at 300-375m	hardiness_av_300-375m
	Zonation of extreme winter cold at 0-75m	hardiness_ex_0-75m
	Zonation of extreme winter cold at 75-150m	hardiness_ex_75-150m
	Zonation of extreme winter cold at 150-225m	hardiness_ex_150-225m
	Zonation of extreme winter cold at 225-300m	hardiness_ex_225-300m
	Zonation of extreme winter cold at 300-375m	hardiness_ex_300-375m
	Microclimatic adjustments to winter cold for valley bottoms	valley_adjust
	Microclimatic adjustments to winter cold for urban sites	urban_adjust

	Microclimatic adjustments to winter cold for coastal proximity	coast_adjust
	Microclimatic adjustments to winter cold for sloping sites	slope_adjust
	Microclimatic adjustments to winter cold for wall proximity	wall_adjust
Growing season solar radiation	Rating of solar radiation at 0-75m	solar_radiation_0-75m
	Rating of solar radiation at 75-150m	solar_radiation_75-150m
	Rating of solar radiation at 150-225m	solar_radiation_150-225m
	Rating of solar radiation at 225-300m	solar_radiation_225-300m
	Rating of solar radiation at 300-375m	solar radiation_300-375m
	Microclimatic adjustments to above for north walls	radiation_north_wall_adj
	Microclimatic adjustments to above for south walls	radiation_south_wall_adj
	Microclimatic adjustments to above for west walls	radiation_west_wall_adj

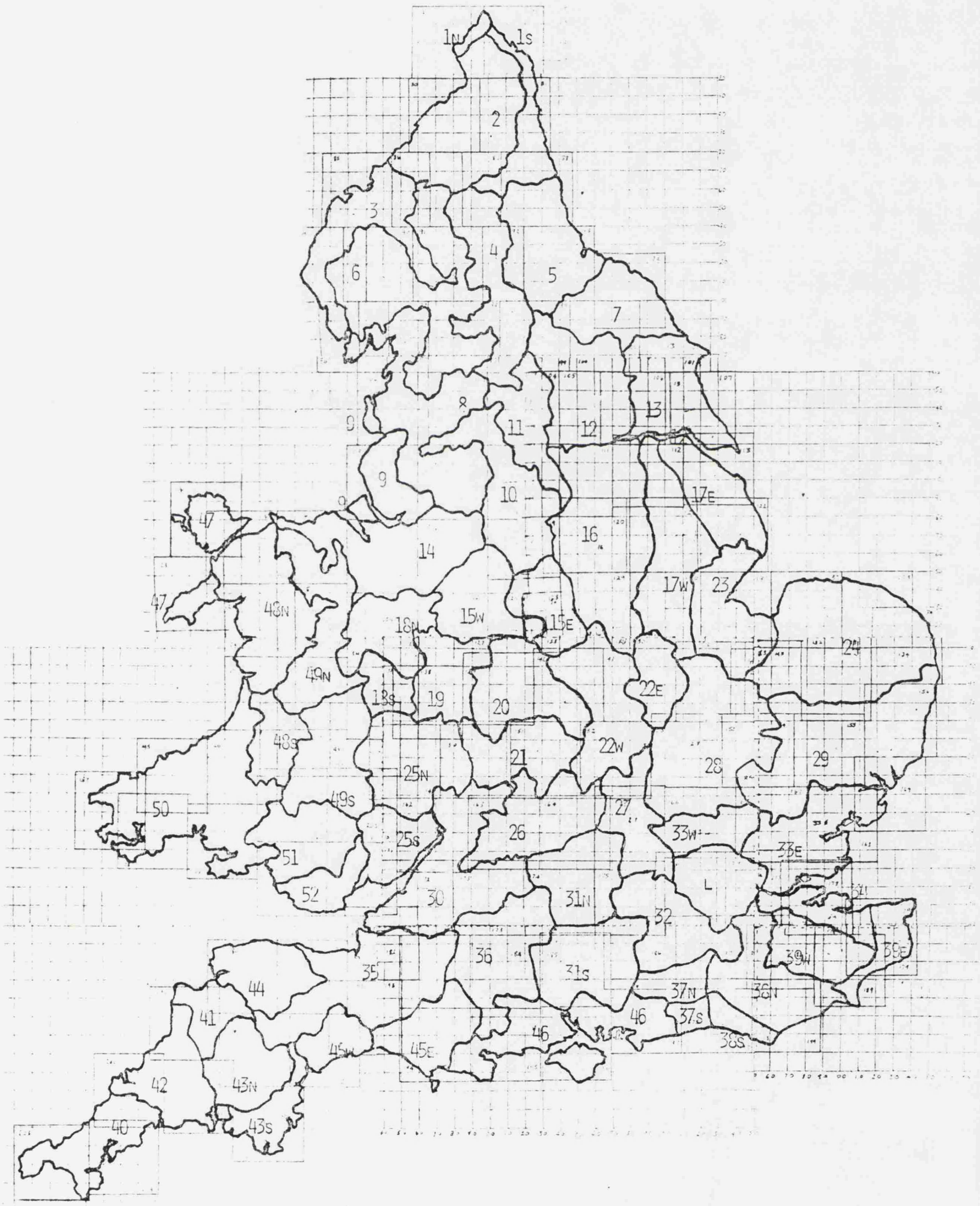
Growing season warmth	Rating of summer warmth at 0-75m	summer_warmth_0-75m
	Rating of summer warmth at 75-150m	summer_warmth_75-150m
	Rating of summer warmth at 150-225m	summer_warmth_150-225m
	Rating of summer warmth at 225-300m	summer_warmth_225-300m
	Rating of summer warmth at 300-375m	summer_warmth_300-375m
	Microclimatic adjustments to above for coastal sites	warmth_coastal_adj
	Microclimatic adjustments to above for south wall	warmth_south_wall_adj
	Microclimatic adjustments to above for east or west walls	warmth_east_wall_adj
Growing season soil moisture stress	Soil moisture deficit at 0-75m	soil_moisture_0-75m
	Soil moisture deficit at 75-150m	soil_moisture_75-150m
	Soil moisture deficit at 150-225m	soil_moisture_150-225m
	Soil moisture deficit at 225-300m	soil_moisture_225-300m
	Soil moisture deficits at 300-375m	soil_moisture_300-375m

The 67 agroclimatic regions from which the data was collected for the period 1941-1970 have been retained to form the Reference Areas of Climatebase.
These assume the role of key identifiers for Climatebase, and when using Climatebase the first step is to locate the planting site within the appropriate reference area. This is done by ascertaining the grid reference of the site via the appropriate 1:50,000 Ordnance Survey Map. The climate reference area can then be ascertained by applying the grid reference to the conversion maps in the User Handbook. This reference number together with the sites altitudinal and microclimatic characteristics,can then be incorporated into a Climatebase retrieval statement as shown in 5.1.1

In response to this information the computer can provide data on five macro-climatic parameters which represent the prevailing climatic limitations of that site. If desired, these values can be incorporated into a request to select plants from Plantbase thereby facilitating the fundamentally important link between climate and plant performance.

Depending upon the construction of the selection request, genotypes which do not satisfactorily fit the climate of the planting site as defined, are either excluded by the computer from further consideration irrespective of their suitability on non climatic parameters or alternatively they are not excluded but the user is informed that they are climatically unsuitable.

Fig 6.2 <u>Climatebase Reference Areas with 1:50,000 Ordnance Survey Grid Overlay</u>



6.3 Zonation of England and Wales for Winter Cold

Climatebase topics involved:

hardiness_av_0-75m
hardiness_av_75-150m
hardiness_av_150-225m
hardiness_av_225-300m
hardiness_av_300-375m

hardiness_ex_0-75m
hardiness_ex_75-150m
hardiness_ex_150-225m
hardiness_ex_225-300m
hardiness_ex_300-375m

This section describes a classification of winter cold designed to act as a reference point against which the hardiness of decorative plants can be studied in order to produce the plant hardiness ratings of Plantbase (see 7.2).

For the purposes of Climatebase the following two classifications of winter cold have been developed:

a) A model based upon the meteorologically "average" winter e.g. a typical combination of cyclonic and weak anticyclonic.

b) A classification model based upon a "10 year extreme" winter. e.g a relatively severe anticyclonic winter such as occurred in 1978-9. Within the time scale of much contemporary landscape this model approximates to a concept of absolute hardiness.

These two models have been constructed as it was recognised that the designer might in some cases be prepared to take a reasonable risk with a small percentage of a sites non-structural vegetation, if in the short term the aesthetic return was sufficiently attractive.

This might be the case with some woody plants such as Hebe speciosa cultivars and the evergreen Ceanothus which grow rapidly and very quickly provide a rich floral display. Given an "average" winter, these and other frost sensitive plants will survive over much of England and Wales, but will certainly be killed in most sites when a 10 year extreme winter occurs.

No attempt has been made to add a third model of winter cold in order to represent the most extreme winters on record. These tend to occur at intervals of approximately 20 years (Manley 1975), and are characterised by persistent advective and extreme radiation frosts. e.g 1946-7, 1962-3, 1981-82.

The number of zones used may appear excessive, until it is recognised that they represent the range of winter cold experienced from coastal Cornwall in an average winter, to upland (300-375m altitude) Northumberland in a 10 year extreme winter. This is in contrast to cartological classifications (Rehder 1951, Hyams 1964), which generally consider only one model of winter at one altitudinal range, frequently sea level. As can be seen from Fig 6.3, despite the large range of winter cold zones employed in Climatebase, in practice, most planting sites will fall within the range of 9-14 (6 zones) in an average winter and 4-12 (9 zones) in an extreme winter.

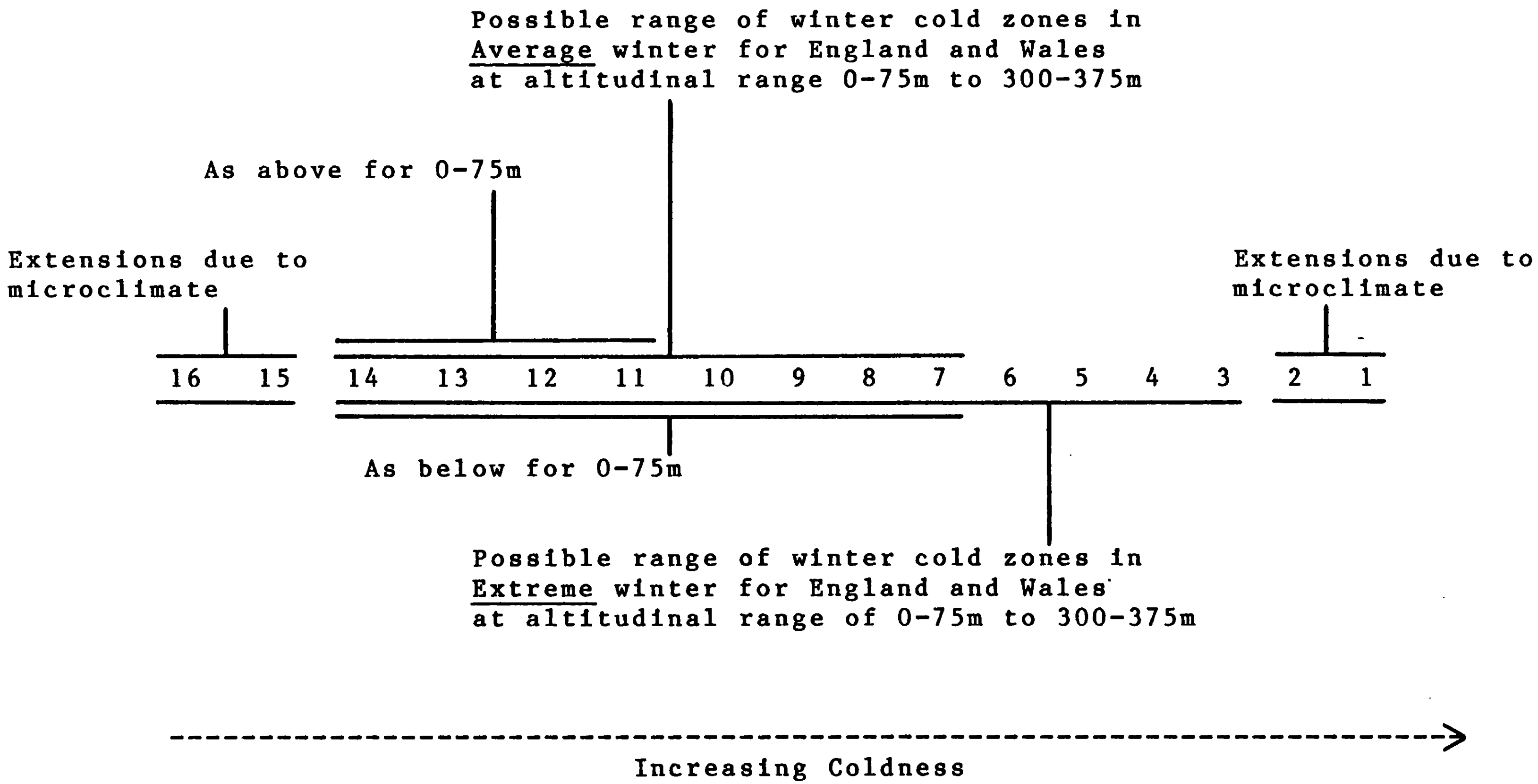
6.3.1 Choice of Parameters and Derivation of Values for Zonation Models

The winter cold zones have been created using data of accumulated day degrees below 0 degrees centigrade for the period 1941-70 (November - Feburary inclusive). Values for the 5 altitudinal ranges have been calculated via lapse rates. Using these does however introduce a degree of error, as they do not normally apply during anticyclonic conditions, when localised phenomena such as inversions frequently reverse the normal gradient of air temperature described by lapse rates.

Microclimatic correction factors have been included in the system in order to attempt to over come some of these difficulties, and in practice the zones created appear to correlate reasonably well with the observed hardiness responses of decorative plants. (Royal Horticultural Society 1948a,b, 1963, 1964).

From a meteorological standpoint, the deficiency of accumulated day degrees below 0 degrees centigrade as an indicator of winter cold is that it cannot be used to distinguish between a situation of uniform moderate cold

Fig 6.3 Range of Zones Around which Classification Models of Winter Cold are Based



and alternating peaks and troughs of extreme cold.

Zones based on January absolute minimum or January mean minimum (Met. Office 1974) might have produced a still better correlation, but these were rejected because of the inadequate geographical coverage of stations recording this parameter.

The base data for accumulated day degrees below 0 centigrade was derived from MAFF Bulletin 35 (Smith 1976b). Values for the 5 altitudinal ranges within each reference area were calculated by using the lapse rate constants in Table 6.2

Table 6.2 <u>Increase in Day-Degrees Below 0 Centigrade with Increasing Height</u>

Source of data: (Smith 1976b)

Northern England[a]	31.5	per	75m
Midland and Eastern England[b]	20.2	"	"
South East England[c]	32.2	"	"
South West England[d]	27.7	"	"
Wales[e]	31.5	"	"

The final data for a meteorologically "average winter" is shown in Table 6.3

Table 6.3 Day Degrees Below Zero Centigrade Data and Resulting Winter Cold Zones for a Meteorologically Average Winter (data derived from Smith 1976b)

Reference	Area	0-75m	75-150m	150-225m	225-300m	300-375m	Winter Cold Zones:				
1n	a	142.6	174.1	-	-	-	11	10	-	-	-
1s	a	143.0	174.5	-	-	-	11	10	-	-	-
2	a	160.9	192.4	223.9	255.4	286.9	10	10	9	8	7
3	a	130.0	161.5	193.0	224.5	256.0	11	10	10	9	8
4	a	144.0	174.5	206.0	237.5	269.0	11	10	9	9	8
5	a	135.0	166.5	198.0	229.5	261.0	11	10	10	9	8
6	a	127.5	159.0	190.5	222.0	253.5	11	11	10	9	8
7	a	118.5	150.0	181.5	213.0	244.5	12	11	10	9	8
8	a	127.0	158.5	190.0	221.5	253.0	11	11	10	9	8
9	a	124.0	155.5	-	-	-	11	10	-	-	-
10	a	110.2	141.7	173.2	204.7	236.2	12	11	10	9	9
11	a	137.8	169.3	200.8	232.3	263.8	11	10	9	9	8
12	a	154.4	185.9	-	-	-	11	10	-	-	-
13	a	138.1	169.6	201.1	-	-	11	10	9	-	-
14	a	118.5	150.0	181.5	213.0	244.5	12	11	10	9	8
15w	b	144.5	164.7	184.9	205.1	225.3	11	10	10	9	9
15e	b	142.1	162.3	182.5	-	-	11	10	10	-	-
16	b	147.3	167.5	187.7	-	-	11	10	10	-	-
17w	b	148.8	169.0	-	-	-	11	10	-	-	-
17e	b	137.4	157.6	-	-	-	11	11	-	-	-
18n	b	131.1	151.3	171.5	191.7	211.9	11	11	10	10	9
18s	b	-	158.6	178.8	199.0	219.2	-	11	10	10	9
19	b	138.8	159.0	179.2	199.4	219.6	11	11	10	10	9
20	b	137.5	157.7	177.9	-	-	11	11	10	-	-

21	b	132.7	152.9	173.1	-	-	11	11	10	-	-
22w	b	148.5	168.7	188.9	-	-	11	10	10	-	-
22e	b	148.3	168.5	188.7	-	-	11	10	10	-	-
23	b	148.8	-	-	-	-	11	-	-	-	-
24	b	146.2	-	-	-	-	11	-	-	-	-
25n	b	113.6	133.8	154.0	174.2	-	12	11	11	10	-
25s	c	91.7	123.2	154.7	186.2	217.7	12	11	11	10	9
26	b	123.2	143.4	163.6	183.8	-	11	11	10	10	-
27	b	126.2	146.4	166.6	-	-	11	11	10	-	-
28	b	140.0	160.2	180.4	-	-	11	10	10	-	-
29	b	141.9	162.1	-	-	-	11	10	-	-	-
30	d	95.3	123.0	150.7	178.4	-	12	11	11	10	-
31n	c	100.1	132.3	164.5	-	-	12	11	10	-	-
31s	c	100.1	132.3	154.5	-	-	12	11	10	-	-
32	c	106.3	138.5	170.7	-	-	12	11	10	-	-
33w	c	109.4	141.6	173.8	-	-	12	11	10	-	-
33e	c	123.9	156.1	188.3	-	-	11	11	10	-	-
34	c	96.2	128.4	-	-	-	12	11	-	-	-
35	d	70.8	98.5	126.2	153.9	-	13	12	11	11	-
36	d	93.0	120.7	148.4	176.1	-	13	11	11	10	-
37n	c	113.6	145.8	-	-	-	12	11	-	-	-
37s	c	83.6	115.8	-	-	-	12	12	-	-	-
38n	c	112.2	144.4	176.6	-	-	12	11	10	-	-
38s	c	81.0	113.2	-	-	-	13	12	-	-	-
39w	c	111.7	143.9	176.1	-	-	12	11	10	-	-
39e	c	90.1	122.3	-	-	-	12	11	-	-	-
40	d	0.0	15.9	43.6	-	-	14	14	13	-	-
41	d	26.2	53.9	81.6	-	-	14	13	12	-	-
42	d	6.9	34.6	62.3	90.0	117.7	14	14	13	12	12

43s	d	18.9	46.6	74.3	102.0	-	14	13	13	12	-
43n	d	41.6	69.3	97.0	124.7	152.4	13	13	12	11	11
44	d	31.9	59.6	87.3	115.0	142.7	14	13	12	12	11
45w	d	53.2	80.9	108.6	136.3	-	13	12	12	11	-
45e	d	66.1	93.8	121.5	-	-	13	12	11	-	-
46	d	72.2	99.9	-	-	-	13	11	-	-	-
47	e	45.1	76.6	108.1	139.6	-	13	13	12	11	-
48n	e	65.2	96.7	128.2	159.7	191.2	13	12	11	11	10
48s	e	-	87.4	118.9	150.4	181.9	-	12	12	11	10
49n	e	82.3	113.8	145.3	176.8	208.3	12	12	11	10	9
49s	e	-	102.5	134.0	165.5	197.0	-	12	11	10	10
50	e	49.1	80.6	112.1	143.6	175.1	13	12	12	11	10
51	e	71.0	102.5	134.0	165.5	197.0	13	12	11	10	10
52	e	72.5	104.0	135.5	167.0	198.5	13	12	11	10	10
L	c	73.2	105.4	137.7	-	-	13	12	11	-	-

L = London

Mean of data(excluding L) = 160.4

By applying the constants in Table 6.4 to the data in Table 6.3 it was possible to derive the values in Table 6.5 which represent the day-degrees below 0 degrees centigrade likely to accompany a 10 year extreme winter.

Table 6.4 Expected Ten Year Extremes of Accumulated Temperatures Below 0 Degrees Centigrade (Percentage of Average) Source of data: (Smith 1976b)

Northern England [a]	175
Midlands, Wales and Southern Western England [b]	200
South Eastern England [c]	225

Table 6.5 Day Degrees Below 0 Degree Centigrade Data and Resulting Winter Cold Zones for a Meteorologically 10 Year Extreme Winter (data derived from Smith 1976b)

Reference	Area	0-75m	75-150m	150-225m	225-300m	300-375m	Winter Cold Zones:				
1n	a	249.5	304.7	-	-	-	8	7	-	-	-
1s	a	250.2	305.4	-	-	-	8	7	-	-	-
2	a	281.6	336.7	391.8	446.9	502.1	7	6	5	3	3
3	a	227.5	282.6	337.7	392.9	448.0	9	7	6	5	3
4	a	252.0	305.4	360.5	415.6	470.7	8	7	5	4	3
5	a	226.2	291.4	346.5	401.6	456.7	9	7	6	4	3
6	a	223.1	278.2	333.4	388.5	443.6	9	8	6	5	3
7	a	207.4	262.5	317.6	372.7	427.9	9	8	7	5	4
8	a	222.2	277.4	332.5	387.6	442.7	9	8	6	5	3
9	a	217.0	272.1	-	-	-	9	8	-	-	-
10	a	192.4	248.0	303.1	358.2	413.3	10	8	7	6	4
11	a	241.1	296.3	351.4	406.5	461.6	8	7	6	4	3
12	a	270.2	325.3	-	-	-	8	6	-	-	-
13	a	241.7	296.8	351.9	-	-	8	7	6	-	-
14	a	207.4	262.5	317.6	372.7	427.9	9	8	7	5	4
15w	b	289.0	329.4	370.0	410.4	541.1	7	6	5	4	3
15e	b	284.2	324.6	365.2	-	-	7	6	5	-	-
16	a	257.8	293.1	328.5	-	-	8	7	6	-	-
17w	a	260.4	295.7	-	-	-	8	7	-	-	-
17e	a	240.4	275.8	-	-	-	8	8	-	-	-
18n	b	262.2	302.6	343.0	383.4	423.8	8	7	6	5	4
18s	b	-	317.2	357.6	398.0	438.4	-	7	6	5	4
19	b	277.6	318.0	358.4	398.8	439.2	8	7	6	5	4

20	b	275.0	315.4	355.8	-	-	8	7	6	-	-
21	b	265.4	305.8	346.2	-	-	8	7	6	-	-
22w	b	297.0	337.4	377.8	-	-	8	7	6	-	-
22e	b	296.6	337.0	377.4	-	-	7	6	5	-	-
23	a	260.4	-	-	-	-	8	-	-	-	-
24	b	292.4	-	-	-	-	7	-	-	-	-
25n	b	227.2	267.6	308.0	348.4	-	9	8	7	6	-
25s	b	183.4	246.4	309.4	372.4	435.4	10	8	7	5	4
26	b	246.4	286.8	327.2	367.6	-	8	7	6	5	-
27	b	252.4	292.8	333.2	-	-	8	7	6	-	-
28	c	315.0	360.4	405.9	-	-	7	5	4	-	-
29	c	319.3	364.7	-	-	-	7	5	4	-	-
30	b	190.6	246.0	301.4	356.8	-	10	8	7	6	-
31n	c	225.2	297.7	370.1	-	-	9	7	5	-	-
31s	c	225.2	297.7	370.1	-	-	9	7	5	-	-
32	c	239.1	311.6	384.0	-	-	9	7	5	-	-
33w	c	246.1	318.6	391.0	-	-	8	7	5	-	-
33e	c	278.8	351.2	423.7	-	-	8	6	4	-	-
34	c	216.4	288.9	-	-	-	9	7	-	-	-
35	b	141.6	197.0	252.4	307.8	-	11	10	8	7	-
36	b	186.0	241.4	296.8	352.7	-	10	8	7	6	-
37n	c	255.6	328.0	-	-	-	8	6	-	-	-
37s	c	188.1	260.5	-	-	-	10	8	-	-	-
38n	c	252.4	324.9	397.3	-	-	8	6	5	-	-
38s	c	182.2	254.7	-	-	-	10	8	-	-	-
39w	c	251.3	323.8	396.2	-	-	8	6	5	-	-
39e	c	202.7	275.2	-	-	-	9	8	-	-	-
40	b	0.0	31.8	87.2	-	-	14	12	12	-	-
41	b	52.4	107.8	163.2	-	-	13	12	10	-	-

42	b	13.8	69.2	124.6	180.0	235.4	14	13	11	10	9
43n	b	83.2	138.6	194.0	249.4	304.8	12	11	10	8	7
43s	b	37.8	93.2	148.6	204.0	-	14	12	11	9	-
44	b	63.8	119.2	1754.6	230.0	285.4	13	12	10	9	-
45w	b	106.4	161.8	217.2	272.6	-	12	10	9	8	-
45e	b	132.2	187.6	243.0	-	-	11	10	8	-	-
46	b	144.4	199.8	-	-	-	11	10	-	-	-
47	b	90.2	153.2	216.2	279.2	-	12	11	9	8	-
48n	b	130.4	193.4	256.4	319.4	382.4	11	10	8	7	5
48s	b	-	174.8	237.8	300.8	363.8	-	10	9	7	5
49n	b	164.6	227.6	290.6	353.6	416.6	10	9	7	6	4
49s	b	-	205.0	268.0	331.0	394.0	-	9	8	6	5
50	b	98.2	161.2	224.2	287.2	350.2	12	10	9	7	6
51	b	142.0	205.0	268.0	331.0	394.0	11	9	8	6	5
52	b	145.0	208.0	271.0	334.0	397.0	11	9	8	6	5
L	c	214.7	287.1	359.6	-	-	9	7	6	-	-

L = London

Mean of data (excluding London) = 316.8

The 12 winter cold zones shown in Figure 6.3 and Table 6.6 have been created around the mean of the day degree below 0 centigrade data in Table 6.3 and 6.5.

Table 6.6 <u>Winter Cold Zones of Climatebase</u>

Day Degrees Below 0 Degrees C	Winter Cold Zones:
<40	14
40-80	13
80-120	12
120-160	11
160-200	10
200-240	9
240-280	8
280-320	7
320-360	6
360-400	5
400-440	4
>440	3

A classification of winter cold based solely upon cyclonic lapse rates provides an unrepresentative picture of conditions in the field, as it cannot account for the significant local deviations that are known to occur. The most important and widespread of these arise because lapse rates do not accurately reflect conditions on the calm still radiation nights associated with anticyclonic circulation systems. In Britain these are the conditions under which low temperature plant injury is most likely to occur. Temperature inversions are often associated with these conditions and the normal pattern of lapse rates are essentially reversed with low lying areas experiencing lower temperatures than more elevated areas. Microclimatic correction factors have been built into Climatebase, in order to account for this and other microclimatic phenomena which are responsible for local deviations from the expected intensity of winter cold.

Very few meteorological stations keep records of acculmulated day-degrees below 0 degrees centigrade, and this has further increased the difficulties of quantifying the influence of microclimate by direct comparison of meteorologically "normal" sites against those with pronounced microclimates.

As a result of these difficulties, in order to obtain values of an appropriate order for microclimatic factors (in terms of wnter cold zones) it has been necessary to adopt a surrogate approach and to compare the percentage deviation in terms of November to January minima (degrees centigrade) of a site where a microclimatic factor is operating from an "adjacent" meteorologically "normal" reference site.

For example, of two adjacent sites a and b, a is 50% colder as measured by November-January mean minima (degrees centigrade) due to the operation of microclimatic phenomena. By referring to data in Table 6.3, site b is found likely to experience 100 dd below 0 centigrade over the period of comparison, then it is not unreasonable to assume site a may experience 150 dd below 0 centigrade for the same period. On the scale in Table 6.6 this value would correspond a microclimatic depression of -1.25 winter cold zones. This approach has been used for all the microclimatic components of Climatebase.

6.3.2. Microclimatic Phenomena Giving Rise to Negative Correction Factors

Climatebase topic involved:

valley_bottom_adjust

a) Low Lying Areas Surrounded by Higher Land

At night under calm, clear, anticyclonic conditions a vegetated surface cools rapidly as it loses longwave radiation to space. The boundary layer of air immediately above this surface is also cooled, increasing in density and consequently attempts to flow to lower altitudes. In doing so the colder air pushes itself under layers of warmer air. This process is known as an inversion and results in an atmospheric temperature stratification with the coldest, heaviest air being found at the lowest levels in contact with the ground.

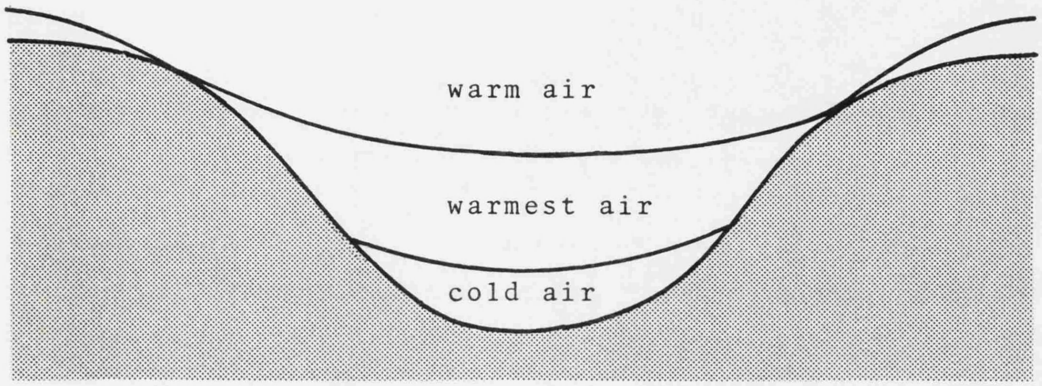
This process results in the phenomenon of frost pockets, or cold islands. Any concave land form is a potential frost pocket under anticyclonic conditions.

Horticulturalists have long since recognised that in low lying sites and or valley basins in particular, this phenomenon extends the risk of frost into what is normally considered the frost free period. It has not been so widely recognised that such locations are widespread, and that depressions as little as one metre deep can develop appreciable temperature differentials (Geiger 1964), and also experience significantly lower winter minima.

The increase in winter cold experienced in such sites can be considerable. Observations by George (1963) demonstrated differences of 5.5 degrees centigrade between the top and bottom of a Welsh valley on radiation nights. Morris & Barry (1963) report differentials of the same order for a valley in the New Forest. The most extreme example of the frost pocket phenomenon so far discovered in England is associated with a narrow dammed valley near Rickmansworth, Hertfordshire which experiences winter minima identical to Braemar on the central Highlands plateau (Hawke 1948). In this particular valley it is not unusual for the night minima to be 8.0-11.0 degrees centigrade lower than a meteorological station at comparable altitude 17 kilometres distant. Although relatively few sites capable of paralelling the Rickmansworth example are likely to be found, less dramatic though significant cold islands are undoubtably widerspread in Britain. (Manley 1944, Hawke 1946, Balchin & Pye 1947).

This process can result in otherwise inconceivable temperature differentials occuring between sites only a few metres apart, and are undoubtably a major factor in

Fig 6.4 Thermal Inversions in Valley Sites
(From Geiger 1964)



the sometimes mystifying pattern of low temperature damage to plants within a small area. Such evidence frequently emerges from surveys of decorative plant hardiness in the field. (Shaw 1978, Beckett 1980 a,b)

Table 6.7 is a comparison of several valley and non valley sites and suggests that this phenomenon operates at varying intensities depending largely upon the area and altitude of the cooling ground in relation to the low lying area. In an attempt to arrive at an adjustment factor that approximates to the majority to situations, a value of -2.0 winter cold zones has been chosen for valley_bottom_adjust.

Table 6.7 Estimated Depression in Terms of Winter Cold Zones (DD Below 0 Centigrade) of Valley Bottom Stations Below Adjacent "Normal" Stations

(data derived from Met. Office 1976)

Stations in Deep Valleys		Average Stations (normal)			
		(51m) Long Ashton [2]	(65m) Cheltenham [2]	(102m) Durham	(128m) Rothamsted
Usk	(21m)	-0.8	-0.7		
Houghall	(37m)			-1.7	
Rickmansworth [1]	(55m)				-3.9

1 Based on data for Braemar, which experiences almost identical minima.(Hawke 1948)

2 Stations themselves in broad open valleys.

It is suggested that this relatively arbitrary value approximates to median examples of this phenomenon in Britain. In practice at some sites, this value will be excessive, whilst at others it will be inadequate. Generalisations such as these are inevitable in an interactive information retrieval system where the user is unlikely to able to adequately quantify his site analysis.

6.3.3 Microclimatic Phenomena Giving Rise to Positive Correction Factors

Climatebase topics involved:

urban_adjust
coast_adjust
slope_adjust
wall_adjust

a) Urban Centres

Urban centres frequently experience dramatically different winter minima from those of surrounding rural areas, a fact which has not escaped the cultivators of decorative plants. (Wright 1976)

These differentials result from the warm air mass or heat island which covers urban areas, and which is best developed on clear, calm radiation nights. Under these conditions the air in the city can be 2.0-5.0 degrees centigrade warmer than surrounding rural areas. (Chandler & Gregory 1976). Most towns (as opposed to cities) with high central building densities will average between 1 and 2 degrees warmer. In effect the size of the city is less important than the density of the buildings (Chandler & Gregory 1976).

Manley (1944) has highlighted the effect of urbania on winter cold differentials for a city of uniform relief, namely Manchester, demonstrating that in January a moderately low density urban site was on average 3.1 degrees centigrade warmer than a comparable rural site 11 kilometres distant. Most towns with reasonably high central building densities will average between 1.0 and 2.0 degrees warmer (Parry 1956)

The following are some of the interactions responsible for these differentials: (Lowry 1968)

i The nature of the cities surfaces, the road and building materials have a heat conductivity approximately three times that of a wet sandy soil, and many times that of a vegetated surface. Correspondingly the former is able to store more energy in a shorter time. The net energy stored in the building-air volume is 15-30% of the prevailing net radiation flux density compared with 5-15% for rural vegetation - air volumes.

ii Surface geometry; the city has a wider variety of shapes and orientations than the natural landscape. The buildings of the city act as a maze of reflectors absorbing some of the radiation and reflecting most of the rest onto other absorbing surfaces.

As air is heated almost entirely by contact with warmer surfaces rather than direct radiation, the city is efficient at heating large volumes of air.

iii Waste heat; the city itself produces an enormous an amount of heat, especially in winter. Combustion processes alone in Sheffield in 1952 produced a heat flux of 14.6 kcal cm^{-2} $year^{-1}$ compared with an estimated solar radiation receipt of 70.0kcal cm^{-2} $year^{-1}$ (Garnett & Bach 1965)

An even more extreme example is provided by Manhatten where, during the winter, combustion processes release heat equivalent to 0.299 cal cm^{-2} min^{-1} (Oke & Hannell 1970), a figure double the solar radiation input.

iv Reduced evaporation; precipitation is rapidly redistributed in the city. In rural areas this does not occur so rapidly and water is more available for evaporation which leads to a cooling of rural air. The same relationships apply to snow.

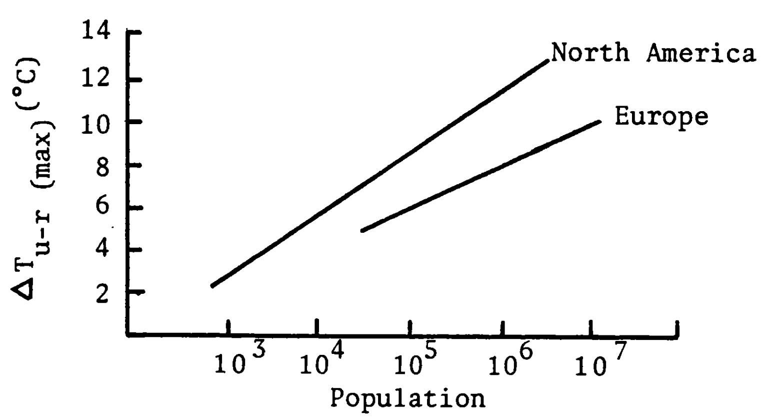
Oke (1978) has shown that the existence and intensity of the heat island correlates with city size, heat island intensity being proportional to the log of population. It is however safest to assume that population is a surrogate index of central building density. Given an adequate building density, even villages of 1000 people are likely to possess a heat island ,although it will be relatively small and easily obliterated by wind.

Table 6.8 Critical Wind Speeds for Elimination of Heat Islands in Different Cities (Oke & Hannell 1970).

City	Population	Critical Wind Speed m s^{-1}
London	8,500,000	12
Montreal (Canada)	2,000,000	11
Bremen (Germany)	400,000	8
Hamilton (Canada)	300,000	6-8
Reading	120,000	4-7
Kumagaya (Japan)	50,000	5
Palo Alto (California)	33,000	3-5

Under advective frost conditions the moderating influence of urban heat islands are likely to be minimal.

Fig 6.5 Relationship Between Maximum Observed Heat Island Intensity (Δt_{u-r}(max)) and Population for North America and European Settlements (Oke 1978)



In practice heat island intensity will vary enormously between different urban areas depending upon building density, size and wind speeds. The urban_adjust correction factor is therefore assessed for urban areas of typical density containing approximately 100,000 inhabitants. Comparisons between a range of urban and rural sites are made in the Appendices, and the resulting data is summarised in Table 6.9

Comparisons of the intensity of winter heat islands are complicated by the presence of other microclimatic factors such as altitude and topography. The urban_adjust rating has been set at + 1.0 winter cold zones, which is considered a minimum representative value for the inner metropolitan area of a conurbation of 100,000 or more inhabitants.

Cities which exceed this size are likely to experience urban-rural differentials in excess of this value.

Table 6.9 Estimated Elevation in Terms of Winter Cold Zones (DD below 0 centigrade of Urban Stations Above Adjacent Rural Stations (data derived from Met. Office 1976)

Increasing Altitude →

Urban Stations:	Rural Stations: 20m Barton Airfield Manchester	35m Wisley	48m Sutton Bonnington	125m Oaken
Nottingham (59m)			1.3	
Manchester (40m)	1.3[1]			
Birmingham (163m)				1.6
London:				
1. Kensington (25m)		1.2		
2. Regents Park (39m)		1.1		
3. Kew (6m)		1.1		
4. Hampstead (137m)		0.8		

1 data from Manley (1944)

b) Proximity to Coasts

Climatebase topics involved:

coast_adjust

All parts of the British Isles lie within 160 km of the sea; the influence of which is felt to a greater or lesser extent in all localities. Whilst in terms of the inland penetration of sea breezes the modified coastal zone may be considered to extend inland as far as 65 km (Smith 1976a), microclimatic modification becomes increasingly weak with distance from the coast. Thermal effects such as differential winter minima are only significant within a narrow coastal strip.

All coastal areas exhibit a more equable temperature range than do inland areas, i.e daily maxima are lower and nightly minima higher. With regard to the latter, coastal-inland differentials may be considerable.

Table 6.10 Comparison of Winter Minima at Coastal and Inland Stations in North Eastern England (data derived from Met. Office 1976)

Station	Altitude m	Approx distance from sea	January mean monthly minima °C	Absolute minimum °C
Tynemouth	29	-	-4.0	-8.9
Cocklepark	99	5 km	-6.0	-12.8
Acklington	42	6.5 km	-6.5	-13.4
Durham	102	16 km	-7.6	-15.0

These differences occur due to the diurnal thermal gradients that exist between land and water surfaces, which in turn drive the land and sea breeze circulation system illustrated in Fig 6.6. The gradient arises because large bodies of water, in contrast to land, are remarkably stable energy stores and respond only slowly to changing thermal conditions (Oke 1978). This is due to:

i Depth of shortwave radiation penetration.

ii Energy absorption is diffused through a large volume

iii Convection and mass transport through fluid motions allow heat losses and gains to be redistributed throughout the volume.

iv Evaporative cooling destabilises the surface layers leading to further mixing.

v Water possesses an exceptionally large thermal capacity and approximately three times as much energy is required to raise a unit of water through the same temperature interval as a soil.

Fig 6.6 <u>Nocturnal Anticyclonic Circulation Responsible for Differential Coastal-Inland Winter Minima (From Oke 1978)</u>

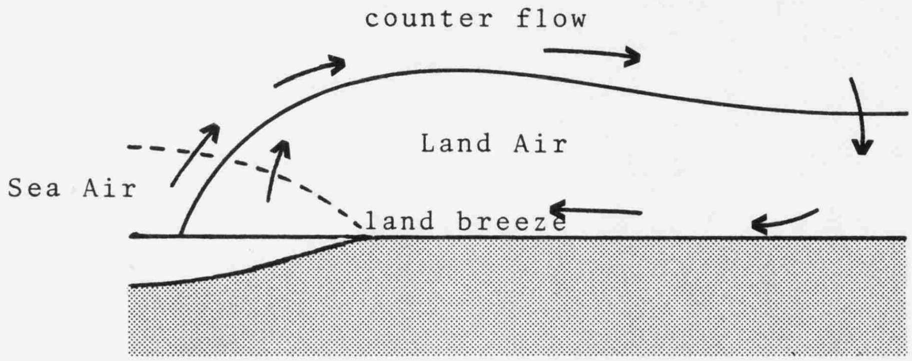


Table 6.11 Estimated Elevation in Terms of Winter Cold Zones (DD Below 0 Centigrade) of Coastal Stations Above Adjacent Inland Stations (data derived from Met. Office 1976)

		Maldon	Acklington	Cannington	Hawarden Bridge	Cockle Park	Exeter Airport	Long Ashton	Bodiam	Wye	Durham	Ushaw	Chopelwood	Writtle	Wrexham	Ambleside	Cranwell	Earls Colne	Porton	Shaftsbury	Lincoln	Nelson	Stoneyhurst	Cambridge
Bexhill	(4)									1.0														
Prestatyn	(4)				1.0										1.0									
Skegness	(5)																1.0				1.8			
Dover	(6)								1.7[1]	1.5														
Morecombe	(7)															1.5						1.9	1.1	
Redcar	(8)		1.0			1.0					1.5	0.9[2]	1.4											
WestonS.Mare	(9)			0.3				0.6																
Sidmouth	(10)						0.5																	
Clacton	(11)	1.2												1.5				0.9						1.7
Tynemouth	(29)		1.8			1.9					2.2	2.0	2.2											
Bournemouth	(40)																		2.2	0.7				
Distance from Coast in Kilometres		3	5	5	6	9	10	10	13	15	20	20	20	20	25	32	35	35	41	41	50	56	58	60

1 Frost Hollow Station 2 Hilltop Station

On most British coasts, a significant reduction in the intensity of winter cold experienced is associated with a narrow strip. The actual width of this coastal strip varies according to the local topography, especially the proximity of higher ground immediately inland (Manley 1944). This is demonstrated in Table 6.10 for the Acklington station, which although only 5 kilometres from the sea displays relatively low minima due to being situated in a part of the coastal plain into which a valley drains cold air from neighbouring uplands. Gregory (1964) has noted similar relationships for sites on the Wirral peninsula.

A comparison of coastal and adjacent inland stations is presented in Table 6.11 (see Appendices for derivation of data). From these comparisons the coast_adjust correction factor has been set at + 1.0 winter cold zones and applies to a 3 km wide coastal strip. The delimiter of 3 km represents the minimum inland extension of the modified thermal zone and may be exceeded in some coastal situations.

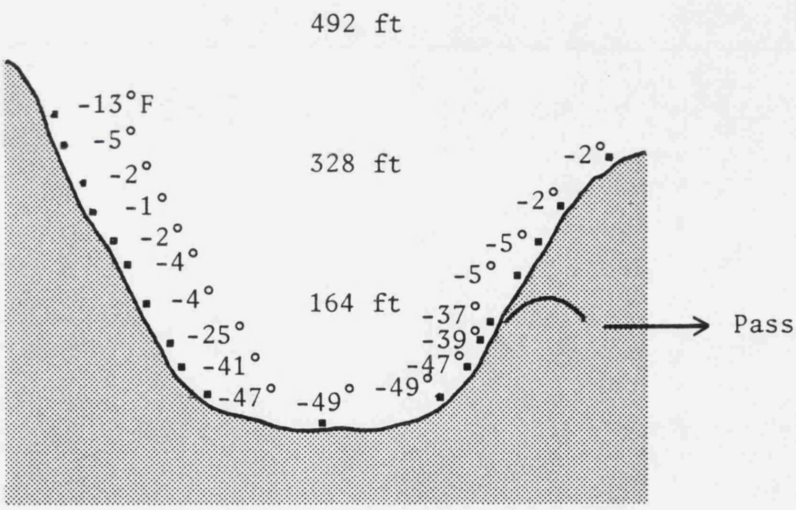
d) Thermal Belts

Climatebase topics involved:

slope_adjust

Under inversion conditions as one ascends the side of a valley, the temperature of the air gradually increases as the top of the cold air pool is reached. Beyond this the air in contact with the shoulders of the valley (the source of the cold air pool) may be almost as cold as that in the valley basin. The intermediate warm zones are known as thermal belts and can be identified on most slopes under radiation conditions. Fig 6.7 illustrates one of the best documented and most dramatic examples of this phenomenon, namely that of the Gstettneralm "sinkhole" near Lunz in Austria.

Fig 6.7 Thermal Belt Development in the Gstettneralm "Sinkhole" (from Griffiths 1976)



The situation shown in Fig 6.7 is an extreme one due to the altitudinal and topographical differentials involved. In Britain, Manley (1944) has identified the operation of this phenomenon on the east slopes of the Malvern Hills, and the same process is at least partially responsible for the high winter minima recorded at the Scarborough meteorological station, and the variations in winter minima in Bath. (Balchin & Pye 1947). Under inversion conditions all sloping ground is potentially warmer than flat areas, the intensity of warmth depending upon the resistance offered to the drainage of cold air from further up the slope. Cross slope barriers which restrict the flow of air cause localised cold air ponding. It is important to realise that these cold pools can occur on an extremely localised basis, and yet be responsible for substantial temperature differentials (Geiger 1964).

The capacity of "thermal belts" to minimise winter cold damage to frost sensitive plants is demonstrated by several important British gardens, most notably the steeply sloping Kiftsgate Court in Gloucestershire.

Although examples of thermal belts undoubtably occur throughout Britain, with the exception of Manleys (1944) investigation into the Perdiswell and Malvern stations, few have been subjected to detailed research. Examination of meteorological records of sites of known topography suggest that this phenomena is of some importance. e.g the Sheffield station (Table 6.12) is relatively warm in relation to comparable urban centres.

The potential "mildness" or freedom from severe cold of sloping sites depends upon many variables, e.g height above the valley floor, the extent and proximity of the uplands, and the nature and extent of cross slope barriers to down slope air flow. The aspect of the slope is of little importance under the radiation frost conditions associated with thermal belts. When cyclonic weather or advective frosts prevail northern slopes are

Table 6.12 <u>Estimated Elevation in Terms of Winter Cold Zones (DD Below Zero Degrees Centigrade) of Sloping Sites Above Adjacent Flat Sites</u> (data derived from Manley 1944, & Met. Office 1976)

Sloping Sites	Flat Sites				
	(28m) Perdiswell	(60m) Belper	(78m) Pontefract	(99m) Huddersfield	(134m) Bradford
Malvern (114m)	1.1				
Sheffield (131m)[1]		1.6	1.2	1.8	1.3

1 Allowance must be made for Sheffields unusually large industrially generated heat island.

usually colder than other aspects, but this is not due to thermal belts, as these are unstable under these conditions.

On the limited meteorological data available, and the field response of plants in collections such as Kiftsgate Court, a slope adjustment factor of + 1.0 winter cold zones is proposed and applies irrespective of aspect to all sloping sites of 15 degrees or more inclination through which the drainage of cold air is not impeded and which are above the level of likely cold air pooling.

This is a necessarily vague definition as it is impossi ble to be more specific without knowledge of the topography of a given site.

e) Proximity to Buildings

Climatebase topics involved:

wall_adjust

The importance of the heat islands associated with towns and cities has already been discussed. In addition to these, localised boundary layer heat islands associated with the air - solid interface of buildings can also develop and contribute further to the differentials between the built and non built environment.

Boundary layer heat islands are generated as a result of the release of radiatively absorbed heat (back radiation) from the surface of masonry type materials.

The process of heat exchange between the wall surface and the air is described by the equation : (Tanner 1974)

$$H = h\ (Ts - Ta)$$

Where Ts = temperature of surface

Ta = " " air

h = transfer coefficient

Due to its capacity as a heat store , even at night the temperature of the wall surface often remains above that of the air, that is the release of stored heat is sufficient to offset almost entirely the net radiative deficit (Oke 1978).

The nocturnal maintenance of a warm boundary layer depends upon wind velocity, i.e the transfer coefficient (h) which is approximately proportional to the square root of wind velocity. On radiation nights wind velocity is minimal and warm layer of air relatively stable giving rise to maximum modification. It follows that in the most extreme winters when windfrosts are prevalent the modifying efect of walls is likely to be slight. The intensity of warmth in the boundary layer may be increased further by the conduction of heat from the interior of a building.The value of wall generated heat islands have long been recognised and exploited by Horticulturalists (Burrage 1976, Wright 1976). The potential intensity of these heat island depend upon the surface characteristics and thermal properties of the building material, and are only important for buildings constructed of rock like materials.

The distance the ameliorated air layer can be expected to extend from a wall surface is not known with any certainty, Crowe (1971) suggests that for bare soils, some of which have similar thermal and conductive properties to material such as concrete, the thermal influence of the surface on the adjacent air is only significant within a layer 10-20 cm deep. For vertical surfaces this figure may be greater. In the absence of published data it has been necessary to estimate the modifying effects of wall on winter cold by comparing the performance of frost sensitive plants growing in both the open and against walls. This bio-assay approach has utilised the winter cold zones of Climatebase (Tables 6.3 and 6.5) as a reference point to allow comparisons to be made in a large numberof collections. The means by which this information was collected and analysed are discussed in 7.2 . As a result of this work it is proposed that the rating for wall_correct should correspond to +2.0 winter cold zones. In order for a wall to exert a significant modifying effect, solar gain, and or conduction from within is required, and this rating applies primarily to walls of south, east and west aspect, although this may be extended to all orientations if conduction from within is significant.

For the purpose of Climatebase, except where buildings are grouped to form isolated air volumes or "canyons" (e.g small courtyards) the useful zone of amelioration is considered not to extend further than 30cm from the wall surface.

6.4 Zonation of England and Wales for Growing Season Solar Radiation

Climatebase topics involved:

solar_radiation_0-75m
solar_radiation_75-150m
solar_radiation_150-225m
solar_radiation_225-300m
solar_radiation_300-375m

The range of solar radiation experienced over England and Wales is relatively small, with average values for the period April-September varying from 200 to 270 w/m^{-2} (measured on a horizontal surface). The range of extremes is however much greater, and for the same period, may fluctuate during daylight hours from 50-900 w/m^{-2} (CIBS 1979).

Zonation of solar radiation or insolation was considered to be an important component of Climatebase for the following reasons:

a) As previously stated, for some decorative taxa the British insolation regime is probably limiting for some of the components of performance. This largely concerns flowering as although many species produce satisfactory vegetative growth at low light levels, they cannot accumulate sufficient dry weight to initiate flower bud development. (Jackson & Palmer 1977b)

b) It is logical to assess the plants response to localised shading at the planting site in the context of the overall radiation regime, i.e 50% shade in Northumberland is not the same in terms of available energy as 50% shade in West Sussex. Thus the response to shading can only be assessed within the framework of an overall zonation of radiation climate.

c) Such a classification provides a reference point allowing cross comparisons to be made of growth, flowering and fruiting performance of decorative plants in response to the insolation climates of the British Isles and the rest of the world.

Section 7.3 describes how the radiation model under discussion has been used to arrive at insolation values for taxa within Plantbase which represent the minimum necessary to initiate and sustain satisfactory plant performance.

6.4.1 Choice of Parameters and Derivation of Values for Classification Models

Solar radiation can be expressed in many ways and indeed the range of units used in the literature creates much unnecessary confusion. Whatever the units used the values are generally calculated in the basis of that incident (direct and diffuse) on a horizontal surface.

The solar radiation zones of Climatebase have been created using the parameter of mean $w\ m^{-2}$ for the period

April - September, incident, not on a horizontal surface but on a simple three dimension plant canopy model.

This approach has been used in order that the effect of proximity to buildings and aspect upon the interception of light by theoretical plant canopies could be compared and used to produce microclimatic correction factors.

$w\ m^{-2}$ is a measure of intensity derived from the power units $mw\ hr^{-1}\ cm^{-2}$. The latter is an inconvenient parameter and rarely used in insolation studies. The inaccuracies introduced as a result of day length anomalies, by using an intensity ($w\ m^{-2}$) as opposed to a power rating ($mw\ hrs^{-1}\ cm^{-2}$) are small and have been ignored.

Base solar radiation data in $mw\ hrs^{-1}\ cm^{-2}$ for the period April-September, incident on a horizontal surface has been abstracted from MAFF Bulletin 35 (Smith 1976b) and converted into $w\ m^{-2}$ for the 67 reference areas of England and Wales using the conversion:

$$w\ m^{-2} = \frac{mw\ hrs^{-1}\ cm^{-2}}{day\ length} \times 100$$

The values for the altitudinal range 0-75m (see column 1, Table 6.14) were then calculated from these areal averages using the constants in column 1 and 2 of Table 6.13

Table 6.13 Decrease in Radiation with Increasing Height as $w.m^{-2}/75m$ (data derived from Smith 1976b)

Month	Column 1 & 2 for radiation incident upon horizontal surfaces		Column 3 & 4 for models intercepting 52% of that incident upon horizontal surfaces	
	Northern England[a]	Southern England[b]	Northern England[a]	Southern England[b]
April	4.0	3.4	2.0	1.8
May	3.6	3.4	1.9	1.8
June	3.1	3.0	1.6	1.6
July	3.3	2.9	1.7	1.5
August	3.4	3.1	1.8	1.6
September	3.1	2.9	1.6	1.5
Mean for April to September	3.4	3.1	1.8	1.6

The next step was to convert these horizontal surface values to the insolation incident upon the free standing 3 dimensional plant canopy model of Climatebase, which intercepts 52% of the radiation incident upon a horizontal surface. (See Table 6.15)

The corrected insolation values for this model at 0-75m altitude are shown in column 2 of Table 6.14

Table 6.14 <u>Derivation of Climatebase Solar Radiation Values for 3 Dimensional Plant Canopy Model</u>

Area	Radiation in $w m^{-2}$ incident upon horizontal surface at 0-75m (April-Sept)	Radiation in $w m^{-2}$ incident upon 3D freestanding plant canopy model at 0-75m (April-Sept)
1n a	223.0	116.0
1s a	219.0	113.9
2 a	214.6	111.6
3 a	226.9	118.0
4 a	225.2	117.1
5 a	222.7	115.8
6 a	216.3	112.5
7 a	230.3	119.8
8 a	233.5	121.4
9 a	239.6	124.6
10 a	226.3	117.7
11 a	226.1	117.6
12 a	233.1	121.6
13 a	229.6	119.4
14 a	231.3	120.3
15w a	230.4	119.8
15e a	228.5	118.8
16 a	230.8	120.0
17w a	237.7	123.6
17e a	236.3	122.9
18n a	236.1	122.8
18s a	240.0	124.8

19	b	232.7	121.0
20	b	233.7	121.5
21	b	236.9	123.2
22w	b	234.6	122.0
22e	b	239.6	124.6
23	a	241.0	125.3
24	a	243.5	126.6
25n	b	240.4	125.0
25s	b	240.4	125.0
26	b	243.7	126.7
27	b	243.3	126.5
28	b	242.5	126.1
29	b	247.1	128.5
30	b	242.7	126.2
31n	b	246.1	128.0
31s	b	250.8	130.4
32	b	247.5	128.7
33w	b	245.6	127.7
33e	b	248.6	129.3
34	b	255.2	132.7
35	b	248.8	129.4
36	b	251.0	130.5
37n	b	253.5	131.8
37s	b	253.5	131.8
38n	b	254.6	132.4
38s	b	266.0	138.3
39w	b	253.8	132.0
39e	b	260.2	135.3
40	b	254.0	132.1
41	b	250.0	130.0

42	b	254.4	132.3
43n	b	245.6	127.7
43s	b	253.5	131.8
44	b	251.3	130.7
45w	b	257.1	133.7
45e	b	255.6	132.9
46	b	260.4	135.4
47	a	236.7	123.1
48n	a	229.4	119.3
48s	b	237.3	123.4
49n	a	233.6	121.5
49s	a	237.3	123.4
50	b	245.0	127.4
51	b	244.6	127.2
52	b	243.8	126.8
L	b	247.3	128.6

Table 6.15 Derivation Growing Season Solar Radiation Zones

Reference Area		0-75m	75-150m	150-225m	225-300m	300-375m	Solar Radiation Zones:				
1n	a	116.0	114.2	-	-	-	2	2	-	-	-
1s	a	113.9	112.1	-	-	-	2	2	-	-	-
2	a	111.6	109.8	108.0	106.2	104.4	2	1	1	1	1
3	a	118.0	116.2	114.4	112.6	110.8	2	2	2	2	2
4	a	117.1	115.3	113.5	111.7	109.9	2	2	2	2	1
5	a	115.8	114.0	112.2	110.4	108.6	2	2	2	2	1
6	a	112.5	110.7	108.9	107.1	105.3	2	2	1	1	1
7	a	119.8	118.0	116.2	114.4	112.6	2	2	2	2	2
8	a	121.4	119.6	117.8	116.0	114.2	3	2	2	2	2
9	a	124.6	122.8	-	-	-	3	3	-	-	-
10	a	117.7	115.9	114.1	112.3	110.5	2	2	2	2	2
11	a	117.6	115.8	114.0	112.2	110.4	2	2	2	2	2
12	a	121.2	119.6	-	-	-	3	2	-	-	-
13	a	119.4	117.6	115.8	-	-	2	2	2	-	-
14	a	120.3	118.5	116.7	114.9	113.1	3	2	2	2	2
15w	a	119.8	118.0	116.2	114.4	112.6	2	2	2	2	2
15e	a	118.8	117.0	115.2	113.4	111.6	2	2	2	2	2
16	a	120.0	118.2	116.4	-	-	3	2	2	-	-
17w	a	123.6	121.8	-	-	-	3	3	-	-	-
17e	a	122.9	121.1	-	-	-	3	3	-	-	-
18n	a	122.8	121.0	119.2	117.4	115.6	3	3	2	2	2
18s	a	-	123.0	121.2	119.4	117.6	-	3	3	2	2
19	b	121.0	119.4	117.8	116.2	114.6	3	2	2	2	2

20	b	121.5	119.9	118.3	116.7	115.1	3	2	2	2	2
21	b	123.2	121.4	119.6	117.8	116.0	3	3	2	2	2
22w	b	122.0	120.4	118.8	117.2	-	3	3	2	2	-
22e	b	124.6	123.0	121.4	-	-	3	3	3	-	-
23	a	125.3	-	-	-	-	3	-	-	-	-
24	a	126.6	-	-	-	-	3	-	-	-	-
25n	b	125.0	123.4	121.8	120.2	-	3	3	3	3	-
25s	b	125.0	123.4	121.8	120.2	118.6	3	3	3	3	2
26	b	126.7	125.1	123.5	121.9	120.3	3	3	3	3	3
27	b	126.5	124.9	123.3	-	-	3	3	3	-	-
28	b	126.1	124.5	122.9	-	-	3	3	3	-	-
29	b	128.5	126.9	125.3	-	-	3	3	3	-	-
30	b	126.2	124.6	123.0	121.4	-	3	3	3	3	-
31n	b	128.0	126.4	124.8	-	-	3	3	3	-	-
31s	b	130.4	128.8	127.2	-	-	4	3	3	-	-
32	b	128.7	127.1	125.5	-	-	3	3	3	-	-
33w	b	127.7	126.1	124.5	-	-	3	3	3	-	-
33e	b	129.3	127.7	126.1	-	-	3	3	3	-	-
34	b	132.7	131.1	129.5	-	-	4	4	3	-	-
35	b	129.4	127.8	126.2	124.6	-	3	3	3	3	-
36	b	130.5	128.9	127.3	125.7	-	4	3	3	3	-
37n	b	131.8	129.8	-	-	-	4	3	-	-	-
37s	b	138.2	136.6	-	-	-	4	4	-	-	-
38n	b	132.4	130.8	129.2	-	-	4	4	3	-	-
38s	b	138.3	136.7	-	-	-	4	4	-	-	-
39w	b	132.0	130.4	128.8	-	-	4	4	3	-	-
39e	b	135.3	133.7	-	-	-	4	4	-	-	-
40	b	132.1	130.5	128.9	-	-	4	4	3	-	-
41	b	130.0	128.4	126.8	-	-	4	3	3	-	-

42	b	132.3	130.7	129.1	127.5	125.9	4	4	3	3	3
43n	b	127.7	126.1	124.5	122.9	121.3	3	3	3	3	3
43s	b	131.8	130.2	128.6	127.0	-	4	4	3	3	-
44	b	130.7	129.1	127.5	125.9	124.3	4	3	3	3	3
45w	b	133.7	132.1	130.5	-	-	4	4	4	-	-
45e	b	132.9	131.3	129.7	-	-	4	4	3	-	-
46	b	135.4	133.8	-	-	-	4	4	-	-	-
47	a	123.1	121.3	119.5	117.7	-	3	3	2	2	-
48n	a	119.3	117.5	115.7	113.9	112.1	2	2	2	2	2
48s	b	123.4	121.8	120.2	118.6	117.0	3	3	3	2	2
49n	a	121.5	119.7	117.9	116.1	114.3	3	2	2	2	2
49s	a	123.4	121.6	119.8	118.0	116.2	3	3	2	2	2
50	b	127.4	125.8	124.2	122.6	121.0	3	3	3	3	3
51	b	127.2	125.6	124.0	122.4	120.8	3	3	3	3	3
52	b	126.8	125.2	123.6	122.0	120.4	3	3	3	3	3
L	b	128.6	127.0	125.4	-	-	3	3	3	-	-

L = London

Mean of data (excluding London) = 121.8

From the final data in Table 6.14 the radiation incident upon the 3 dimensional canopy model at 75-150m, 150-225m, 225-300m, and 300-375m was calculated using the constant in columns 3 and 4 of Table 6.13.

Four growing season solar radiation zones have been created around the mean of the data and are shown in Table 6.16

Table 6.16 <u>Growing Season Solar Radiation Zones of Climatebase</u>

Solar radiation April-September w m^{-2}	Solar radiation zone
<110	1
110-120	2
120-130	3
>130	4

(mean of data = 121.8)

6.4.2 Influence of Microclimate on Solar Radiation

Climatebase topics involved:

radiation_north_wall_adj
radiation_east_wall_adj
radiation_south_wall_adj

The amount of solar radiation available to the plant depends upon the interplay between the following factors:

a) The overall radiation climate as determined by latitude, season, and atmospheric effects. (i.e the values in Table 6.15).
b) The local radiation climate, determined by aspect, topography, shading and reflection.
c) The characteristics of the plants foliage canopy.

The solar radiation that the cultivated plants canopy intercepts is only a percentage of the maximum available and can be increased or indeed decreased by site selection, or a manipulation of the site or plant (Landsberg 1972-3).

The efficiency of the urban canyons formed by buildings, as solar radiation collectors has been mentioned in 6.3.3. This section considers the consequences of this environment in terms of photosynthetic potential for plants adjacent to the walls of buildings.

In order to attempt to quantify these effects and incorporate them into Climatebase it was necessary to develop a simple 3 dimensional model which could represent an idealised woody plant canopy. This model was based on the following assumptions:

a) Should be of simple geometry such as a cube or stacked cube as in the solid model studies of Jackson (1980)
b) Photosynthetic activity would be considered to be limited to the surface of the model only i.e LAI would equal the incident surface area of the model.
c) The model would be of the same overall photosynthetic surface area whether free standing or against a wall.

The models used are a gross simplification of actual plant canopies, but serve as the best simple geometric forms for the very wide range of woody plants under consideration.

As mentioned in c), all the models have the same "photosynthetic" surface area irrespective of overall geometry or location, i.e whether the model has 5 sides to intercept radiation or only 4. This is based on the premise that two specimens of the same clone will, when grown under conditions that are identical in all respects other than one being free standing and the other being against a wall, both maintain approximately the same LAI. This requires the latter specimen to adjust its canopy design in order to compensate for the presence of the wall, (i.e the loss of a photosynthetic side). In reality a plant may achieve this by leaf orientation, in the model it is assumed to occur via an increase in the surface area of the remaining sides.

In arriving at a Climatebase canopy reference model, the photosynthetic potential of the following models have been investigated:

free standing cube
free standing stacked cube
cube attached to north wall
cube attached to east and west wall
cube attached to south wall
stacked cube attached to north wall
stacked cube attached to east and west wall
stacked cube attached to south wall
flattened (against wall) cube attached to north wall
flattened (against wall) cube attached to east and west wall
flattened (against wall) cube attached to south wall
square attached to north wall
square attached to east and west wall
square attached to south wall

All of these models have a photosynthetic surface of $5m^2$, and the radiation capturing capacity of each has been calculated at two latitudes using base data abstracted from the Solar Data Guide (CIBS 1979). The mean of the free standing cube and stacked cube were chosen for the reference model. The results of these calculations are summarised in column 3 of Table 6.17 as $w\,m^{-2}$ of photosynthetic surface. Model dimensions and workings are contained in the Appendices.

Table 6.17 Radiation Capturing Capacity of Various Canopy Models Compared with a Horizontal Surface

Model	Latitude (degrees North)	Incident radiation in w/m^{-2} April-Sept	Mean for group w/m^{-2}
Horizontal Surface	50	282.5	275.8
	55	269.1	
Free Standing cube	50	149.8	143.5 (52% of horizontal)
" " "	55	151.8	
Free Standing Stacked Cube	50	134.7	
" " "	55	137.8	
Cube Attached to North Wall	50	149.4	103.8
" " "	55	147.9	
Stacked Cube Attached to North Wall	50	130.2	
" " "	55	130.4	
Flat Cube Attached to North Wall	50	99.9	
" " "	55	100.1	
Square to Attached North Wall	50	35.0	
" " "	55	37.5	

Cube Attached to East or West Wall	50	152.3	
" " "	55	154.1	
Stacked Cube Attached to East or West Wall	50	133.5	
" " "	55	137.6	
			144.2
Flat Cube Attached to East or West Wall	50	145.7	
" " "	55	147.9	
Square Attached to East or West Wall	50	140.0	
" " "	55	142.5	
Cube Attached to South Wall	50	178.5	
" " "	55	180.4	
Stacked Cube Attached to South Wall	50	163.4	
" " "	55	167.6	
			168.8
Flat Cube Attached to South Wall	50	166.3	
" " "	55	174.9	
Square Attached to South Wall	50	151.7	
" " "	55	167.5	

In the wall attached models allowance has to be made for the contribution of light reflected off the backing wall. The amount of radiation made available to the plant in this way depends upon the density, structure, LAI of the plants canopy and the albedo of the wall surface.

Jackson (1980) has estimated that the canopies of orchard trees characteristically intercept 60-75% of incident light, e.g only 60-75 photons out of every 100 that hit the plant. The remaining 25-40 pass through the canopy, hit the soil surface and are lost by reflection back into the atmosphere.

The undersides of plant leaves can generally absorb radiation as efficiently as the upper surfaces, and efficient reflectance of this lost radiation back into the canopy can further contribute to photosynthetic efficiency.
Table 6.18 summarises typical albedos for common building materials.

Table 6.18 Albedos of Common Building Materials (from Beckett 1931)

Material	Range	Average
Brick	0.10-0.35	0.23
Concrete	0.20-0.40	0.30
Stone	0.20-0.35	0.28
		Mean =0.27

N.B The spectral quality of reflected radiation is little changed.

For a wall of known aspect, e.g. north ,south, east or west, given an extinction coefficient (% of light intercepted by the canopy) and the albedo of the surface it is possible to estimate the amount of extra radiation made available to the plants canopy from this source by using the group means in Table 6.17 .

For example:

$$\left(\begin{array}{l}\text{Mean radiation}\\ \text{in watts } m^{-2}\\ \text{of canopy model}\\ \text{surface}\end{array}\right) \times \left(\begin{array}{l}\text{transmittance of}\\ \text{light through}\\ \text{canopy (1 - extinction}\\ \text{coefficient)}\end{array}\right) \times \text{wall albedo}$$

= <u>additional radiation resulting from wall location</u>

Assuming an extinction coefficient of 0.25 (transmittance = 1 - 0.75) and a wall albedo of 0.27, the additional radiation available to the mean group model as a result of wall relectance is as follows:

a) North wall models (see Table 6.17)

$103.8 \times 0.25 \times 0.27 = 7.0\ w\ m^{-2}$

b) East and west wall models (see Table 6.17)

$144.2 \times 0.25 \times 0.27 = 9.7\ w\ m^{-2}$

c) South wall models (see Table 6.17)

$168.8 \times 0.25 = 11.4\ w\ m^{-2}$

This microclimatically derived source of additional radiation is shown in Table 6.19.

The percentage deviation values in the final column of Table 6.19 have been utilised in order to express the modifying effect of wall proximity and aspect in terms of the overall solar radiation zones of Climatebase. This was done by taking the mean of the data in Table 6.15 and proceeding as follows:

$$\left[\text{mean of solar radiation zone data (121.8)} \times \text{\% deviation of given wall aspect}\right] - \text{mean of solar radiation zone data (121.8)}$$

= <u>solar radiation zone change due wall proximity and aspect</u>

a) For the group mean of the north wall models, the deviation from the mean of solar radiation zone data =

$(121.8 \times 0.77) - 121.8 = -28.0\ w\ m^{-2}$

North wall locations represent a depression of -2.8 solar radiation zones, therefore radiation_north_wall_adj = -3.0 solar radiation zones.

b) For east or west walls

$(121.8 \times 1.07) - 121.8 = 8.5\ w\ m^{-2}$

East or west wall locations represent an elevation of 0.8 solar radiation zones, therefore radiation_east_wall_adj = 1.0 solar radiation zones.

c) For south walls

$(121.8 \times 1.25) - 121.8 = 31.7\ w\ m^{-2}$

South wall locations represent an elevation of 3.2 solar radiation zones, therefore radiation_south_wall_adj = 3.0 solar radiation zones.

These 3 microclimatic correction factors have been incorporated into Climatebase and present the user with a more realistic picture of the radiation climate of the planting site.

Table 6.19 Contribution of Wall Reflectance to Radiation Available to Wall Attached Models

Model	Mean Capturing Capacity of Group $w\ m^{-2}$	Back Radiation from Wall Reflectance $w.\ m^{-2}$	Corrected Mean $w\ m^{-2}$	Corrected Mean as % of that Captured by Free Standing Model $w.\ m^{-2}$
North Wall Attached Group	103.8	7.0	110.8	77.2
East or West Wall Attached Group	144.2	9.7	153.9	107.2
South Wall Attached Group	168.8	11.4	180.2	125.6

6.5 Zonation of England and Wales for Growing Season Warmth

Climatebase topics involved:

summer_warmth_0-75m
summer_warmth_75-150m
summer_warmth_150-225m
summer_warmth_225-300m
summer_warmth_300-375m

As a product of many competing interactions, air temperature regimes are apt to fluctuate widely over relatively short distances, and England and Wales experience a far more diverse range of growing season temperature regimes, than insolation regimes. Due to its oceanic climate Britains growing season temperatures are relatively low compared with continental land masses at equivalent latitudes.

Consequently in Britain, the influence of increasing altitude and exposure on air temperature is much more immediate and dramatic than in continental climates, as can be seen in the altitude at which the respective tree lines occur (Griggs 1938, Millar 1964). The performance of decorative plants in response to growing season temperature is discussed in depth in Section 7.3

6.5.1 Choice of Parameters and Derivation of Values for Zonation Models

The warmth of the growing season has been estimated by using the parameter of accumulated day degrees above 10 degrees centigrade for the period May-October.

Accumulated heat units were chosen as the basis of the zonation because they provide a more accurate indication of growing season warmth than do parameters such as July means. (Gregory 1954)

Workers such as Anderson and Fairburn (1955) and Fairburn (1968) have used the parameter of the total number of days when the air temperature rises above a base value (frequently 6.0 degrees centigrade) in their classifications of the climate of the growing season.

The author considers the length of the growing season approach to be unsatisfactory for woody and many other species in a temperate climate, as unlike agricultural monocots the developmental processes of most decorative plants occur not as a continuum, but as well defined bursts of activity. Consequently for many of these plants what is most important is not necessarily a lengthy growing season, but the existence of specific environmental conditions e.g air temperatures above 15 degrees centigrade, at sensitive phases in the plants development.

Day degrees above 10 degrees centigrade data for the period May-October 1941-1970 was extracted from MAFF Bulletin 35,(Smith 1976b) as areal means. From this, values for the altitudinal ranges of 0-75m, 75-150m, 150-225m, 225-300m, 300-375m were calculated for the 67 reference areas of Climatebase by using the lapse rate constants in Table 6.20.

Table 6.20 Decrease in May-October DD Above 10 Degrees Centigrade with Height

	(DD per 75m)
Northern England and Wales[a]	60.0
Midlands, East, and South East England[b]	78.7
South West England[c]	84.4

The resulting data is shown in Table 6.21.

Table 6.21 DD Above 10 Degrees Centigrade Data for May-October and Resulting Summer Warmth Zones (data derived from Smith 1976b)

Reference Area		0-75m	75-150m	150-225m	225-300m	300-375m	Resulting Summer Warmth Zones:				
1n	a	508.6	448.6	-	-	-	2	2	-	-	-
1s	a	537.8	477.8	-	-	-	3	2	-	-	-
2	a	591.2	531.2	471.2	411.2	351.2	3	3	2	1	1
3	a	607.2	547.2	487.2	427.2	367.2	3	3	2	2	1
4	a	667.0	607.0	547.0	487.0	427.0	4	3	3	2	2
5	a	627.6	567.6	507.6	447.6	387.6	3	3	2	2	1
6	a	667.8	607.8	547.8	487.8	427.8	4	3	3	2	2
7	a	637.6	577.6	517.6	457.6	397.6	3	3	2	2	1
8	a	727.8	667.8	607.8	547.8	487.8	4	4	3	3	2
9	a	712.4	652.4	-	-	-	4	4	-	-	-
10	a	754.6	694.6	634.6	574.6	514.6	5	4	3	3	2
11	a	735.4	675.4	615.4	555.4	495.4	4	4	3	3	2
12	a	726.2	662.2	-	-	-	4	4	-	-	-
13	a	703.2	643.2	583.2	-	-	4	4	3	-	-
14	a	787.0	727.0	667.0	607.0	547.0	5	4	4	3	3
15w	a	770.2	710.2	650.2	590.2	530.2	5	4	4	3	3
15e	a	798.2	738.2	678.2	-	-	5	4	4	-	-
16	a	777.8	717.8	657.8	-	-	5	4	4	-	-
17w	a	773.6	713.6	-	-	-	5	4	-	-	-
17e	a	712.6	652.6	-	-	-	4	4	-	-	-
18n	a	801.7	741.7	681.7	621.7	561.7	5	4	4	3	3
18s	b	-	732.3	653.6	574.9	496.2	-	4	4	3	2

19	b	797.3	718.6	639.9	561.2	482.5	5	4	3	3	2
20	b	832.3	753.6	674.9	-	-	5	5	4	-	-
21	b	817.7	739.0	660.3	-	-	5	4	4	-	-
22w	b	828.4	749.7	671.0	-	-	5	4	4	-	-
22e	b	815.6	736.9	658.2	-	-	5	4	4	-	-
23	b	748.3	-	-	-	-	4	-	-	-	-
24	b	775.6	-	-	-	-	5	-	-	-	-
25n	b	843.4	764.7	686.0	607.3	528.6	5	5	4	3	-
25s	b	857.6	778.9	700.2	621.5	542.8	5	5	4	3	3
26	b	859.4	780.7	702.0	623.3	-	5	5	4	3	-
27	b	867.9	789.2	710.5	-	-	6	5	4	-	-
28	b	834.3	755.6	676.9	-	-	5	5	4	-	-
29	b	817.0	738.3	659.6	-	-	5	4	4	-	-
30	c	879.9	795.5	711.1	626.7	-	6	5	4	3	-
31n	b	877.9	799.2	720.5	-	-	6	5	4	-	-
31s	b	862.9	784.2	705.5	626.8	-	6	5	4	3	-
32	b	860.6	781.9	703.2	-	-	6	5	4	-	-
33w	b	897.4	818.7	740.0	-	-	6	5	4	-	-
33e	b	852.6	773.9	695.2	-	-	5	5	4	-	-
34	b	901.4	822.7	744.0	-	-	6	5	4	-	-
35	c	843.3	758.9	674.5	-	-	5	5	4	-	-
36	c	866.8	782.4	698.0	613.6	-	6	5	4	3	-
37n	b	832.7	754.0	-	-	-	5	5	-	-	-
37s	b	852.7	774.0	-	-	-	5	5	-	-	-
38n	b	848.5	769.8	691.1	-	-	5	5	4	-	-
38s	b	859.0	780.3	-	-	-	5	5	-	-	-
39w	b	874.5	795.8	717.1	-	-	6	5	4	-	-
39e	b	861.5	-	-	-	-	6	5	-	-	-
40	c	815.9	731.5	647.1	-	-	5	4	4	-	-

41	c	792.4	708.0	623.6	-	-	5	4	3	-	-
42	c	800.2	715.8	631.4	547.0	646.6	5	4	3	3	2
43s	c	823.7	739.3	654.9	570.5	-	5	4	4	3	-
43n	c	822.3	737.9	653.5	569.1	484.7	5	4	4	3	2
44	c	830.9	746.5	662.1	577.7	493.3	5	4	4	3	2
45w	c	816.2	731.8	647.4	563.0	-	5	4	4	3	-
45e	c	832.2	747.8	663.4	-	-	5	4	4	-	-
46	c	840.2	755.8	-	-	-	5	5	-	-	-
47	a	656.6	596.6	536.6	476.6	-	4	3	3	2	-
48n	a	664.2	604.2	544.2	484.2	424.2	4	3	3	2	2
48s	a	-	671.0	611.0	551.0	491.0	-	4	3	3	2
49n	a	745.6	685.6	625.6	565.6	505.6	4	4	3	3	2
49s	a	-	732.2	672.2	612.2	552.2	-	4	4	3	3
50	a	703.4	643.4	583.4	523.4	463.4	4	4	3	2	2
51	a	763.4	703.4	643.4	583.4	523.4	5	4	4	3	-
52	a	812.4	752.4	692.4	632.4	572.4	5	5	4	3	3
L		870.2	791.5	712.8	-	-	6	5	4	-	-

L = London

Mean of data (excluding London) = 638.7

Six growing season warmth (summer_warmth) zones were created around the mean of the data as shown in Table 6.22

Table 6.22 <u>May-October Summer Warmth Zones of Climatebase</u>

Mean of data = 638.7

Summer Warmth May-October in DD Above 10 degrees C	Summer Warmth Zone
<420	1
420-530	2
530-640	3
640-750	4
750-860	5
>860	6

6.5.2 <u>Influence of Microclimatic Phenomena on Growing Season Warmth</u>

Climatebase topics involved:

warmth_coastal_adj

warmth_east_wall_adj

warmth_south_wall_adj

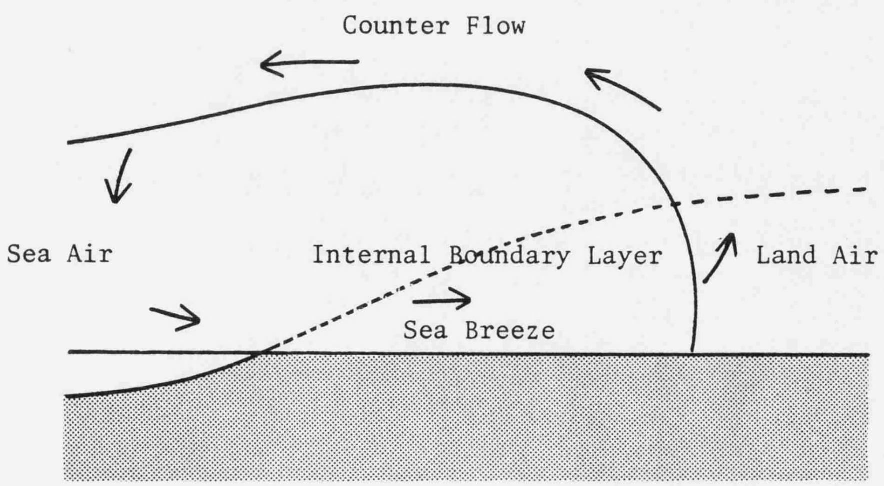
a) <u>Coastal Proximity</u>

Due to the "sea breeze" circulation system which occurs at ocean shorelines and boundaries, coastal locations accumulate fewer heat units than do inland regions.

During the day air overlying land is readily heated by convection, whilst air overlying the ocean warms up much more slowly due the capacity of water to efficiently redistribute heat. This temperature gradient produces land-water air pressure differentials, and ultimately sea breezes (see Fig 6.8). The cooler more humid sea air advects across the coast and wedges under the warmer land air, thereby sustaining relatively low coastal air temperatures.

These sea breezes are particularly marked during anticyclonic weather. On a cloudy or windy days these local winds are largely obliterated, and coastal-inland temperature differentials may remain small.

Fig 6.8 <u>Daytime Sea Breeze Circulation Systems</u>
(from Oke 1978)



As with many of the microclimate correction factors of Climatebase the absence of comparable data for a normal reference station and a station where microclimatic effects are known to operate has made it necessary to estimate the magnitude of the microclimatic phenomena by comparing surrogate data. (In this case May-October mean maxima in degrees centigrade). For example, the effect of coastal proximity in terms of the accumulated day degrees above 10 degrees centigrade upon which the summer warmth zones are based, can be estimated from:

Microclimatic effect of coastal proximity
in terms of DD above 10 degrees centigrade =

$$\left[\begin{array}{l}\text{May-October DD}\\ \text{above 10 degrees}\\ \text{centigrade for}\\ \text{inland reference}\\ \text{station}\end{array} - \begin{array}{l}\text{deviation of}\\ \text{coastal stations}\\ \text{from inland in}\\ \text{terms of mean}\\ \text{monthly maxima}\\ \text{in degrees}\\ \text{centigrade}\end{array}\right] \times \begin{array}{l}\text{May-October DD}\\ \text{above 10 degrees}\\ \text{centigrade for}\\ \text{inland reference}\\ \text{station}\end{array}$$

Workings for a range of coastal and comparable inland sites are to be found in the Appendices.The results of these comparisons are summarised in Table 6.23.

Assessment of coastal inland differentials has been complicated by the small number of comparable stations and variables such as proximity to the sea, altitude and a range of unknowns such as exposure as determined by topography and the presence or absence of buildings and vegetation.

The inland extension of the cooler coastal zone is greatest where the coastal topography is gentle, as in

Table 6.23 Estimated Summer Warmth Zone Depression of Coastal Stations Below that of Inland Stations (data from Met. Office 1976)

Coastal Stations \ Inland Stations	Maldon	Acklington	Hawarden Bridge	Cockle Park	Exeter Airport	Long Ashton	Bodiam	Wye	Durham	Houghall	Ushaw	Writtle	Wrexham	Cranwell	Earls Colne	Leckford	Lincoln	S Farnborough	Cambridge
Colwyn Bay			-0.5										-0.3						
Tynemouth		0.0		-0.3					-0.4	-0.5	-0.2								
Clacton	-0.8											-0.9			-0.9				-1.0
Sidmouth					-0.4														
Weston S Mare						-0.2													
Bognor																-0.7		-1.0	
Dover							-0.5	-0.5											
Skegness														-0.3			-0.3		
	3	5	6	9	10	10	13	15	19	20	20	20	25	35	35	35	50	55	60

----------- Increasing Distance From the Coast (kms) ---------------------->

Tabulated values (summer warmth zones) demonstrate the degree to which coastal stations experience cooler summers than adjacent inland stations the case of coastal plain transects such as Skegness to Cranwell.

The effect of altitude is highlighted by the Tynemouth - Ushaw comparison, the latter station being 20 km inland, but as a result of its altitude of 181 m it experiences very similar summer warmth conditions to the coastal station. As a result of these studies a microclimatic correction factor of -0.5 summer warmth zones is proposed and applies to a 3.0 kilometre wide coastal strip. Sites within this zone which are sheltered by woodland or land form are unlikely to experience a reduction in summer warmth of this magnitude.

b) Proximity to Buildings

As a result of the division of opinion amongst urban climatologists such as Lowry (1968) and Chandler (1962) regarding the intensity and stability of urban summer heat islands, quantification of the influence of urbania in terms of summer warmth zones has not been attempted.

Although it is therefore debatable that overall, the urban area experiences significantly higher summer temperatures than do surrounding rural areas, "built up" areas do contain localised but often intense heat islands. These are frequently associated with the interface of the building exterior and the air, and occur as a result of the greater thermal capacity of most building materials over the biological surfaces that tend to predominate in natural environments.

Table 6.24 summarises Landsburgs (1970) observations of wall and air temperature differentials in the courtyard of an isolated group of buildings in an otherwise rural location.

Table 6.24 Summer Temperatures in Degrees Centigrade in a Courtyard

All temperatures in degrees centigrade

Time	Mean Air Temperature in Courtyard	Surface Temperature of Walls facing: North	East	South	West
16.20	30.6	32.0	35.0	34.5	44.0
Sunset 19.15					
19.34	28.3	30.5	31.0	31.5	33.5
21.15	25.6	27.5	28.0	29.5	29.5

As might be expected wall temperatures are consistently higher than air temperature and this differential persists long after direct insolation has ceased.

Warming of the air will occur at the junction of the wall air boundary in accordance with the heat exchange equation:

$$H = h\ (Ts - Ta)$$

(Ts - Ta) = temperature difference between the wall surface and the air and h = the transfer coefficient.

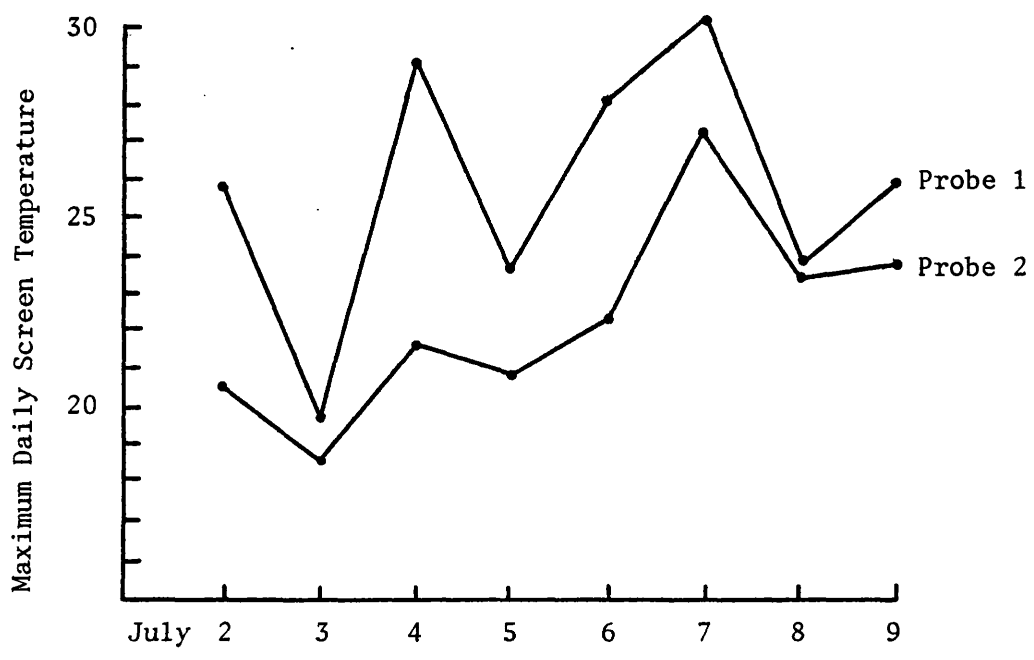
Ts (surface temperature) is dependent upon the albedo of wall material and its thermal characteristics.

H = available heat

The extent to which the temperature of the air boundary layer is elevated depends largely upon the prevailing wind velocity as turbulent air mixing at the surface of exposed wall may largely obliterate these localised heat islands.

Fig 6.9 illustrates differences recorded by the author, between air temperature at 15 and 600 cm from a south facing wall. Data represents screen temperatures at 100cm recorded via a Honeywell Multichannel Recorder.

Fig 6.9 Observations of the Influence of Wall Proximity on Air Temperature



Probe 1 = 15cm from wall

Probe 2 = 600cm from wall

The existence of wall generated heat islands was known centuries before such phenomena could be accurately measured,and this microclimate has been and still is exploited by horticulturalists to successfully cultivate taxa unable to perform or survive as free standing specimens within the temperature regime defined by screen temperatures. Manley (1975) cites an example of two plum trees Prunus domestica which fruit regularly against the south wall of a house at 340m in the Cumbrian Pennines.

Professional interest in microclimates generated by the surface of buildings is likely to increase given contemporary trends towards curtilage planting. Although the physical interactions responsible for the occurrence of localised heat islands are well understood the author has been unable to locate any studies involving:

i Actual field measurements of temperature differentials from screen temperatures arising from wall generated heat islands.

ii Measurements of the distance the zone of significantly ameliorated temperature extends from the wall surface under given conditions.

In the absence of this information, in order to register this important microclimatic element in the structure of Climatebase, the likely magnitude of this phenomenon has been estimated from the known and observed response of plants growing in these locations.

After studying the extensive plant performance survey data collected during the project a value of +2.0 summer warmth zones is proposed to represent the effect of the heat island at both south and west walls.

The depth of this modified boundary air layer remains an unknown although for the purposes of Climatebase it will be considered to extend outwards from the wall for 30 centimetres.

6.6 Zonation of England and Wales for Soil Moisture Stress

Climatebase topics involved:

soil_moisture_deficit_0-75m
soil_moisture_deficit_75-150m
soil_moisture_deficit_150-225m
soil_moisture_deficit_225-300m
soil_moisture_deficit_300-375m

In Britain, although monthly precipitation is relatively uniform throughout the year, evaporation generally exceeds precipitation during the summer months exposing plants to soil moisture stress (MAFF 1967).

With the exception of the first year of the establishment period, for most cultivated mesophytes this stress is rarely sufficient to do more than depress the level of vegetative performance in terms of extension growth per unit time. Soil moisture stress will also commonly induce varying degrees of morphological change in the decorative phenotype e.g leaf size, branching density, which may or may not be considered desirable by the designer.

In Britain therefore, on soils with reasonable water storage capacity and with the proviso of the establishment period, soil moisture stress generally defines levels of performance rather than ultimate survival or failure as is the case in more continental climates.

6.6.1 Choice of Parameters and the Derivation of Values for the Zonation Model

The forestry orientated climate classifications of Anderson and Fairburn (1955) and Fairburn (1968) use the parameters of growing season rainfall qualified by a measure of growing season warmth to indicate potential soil moisture status.

Although this approach loosely differentiates between the actual soil moisture status of areas experiencing equivalent rainfall but widely dissimilar summer temperatures, it must be regarded as inadequate as it suggests, but does not in practice integrate precipitation and evaporation i.e the soil moisture balance.

Consequently for Climatebase the parameter of growing season soil moisture deficit has been used rather than a measure of precipitation only (Met. Office 1968).The soil moisture deficit is the amount of water in mm by which the soil moisture status falls below field capacity, i.e the amount of precipitation or irrigation necessary to return the soil to field capacity.

An obvious criticism of this parameter is that it fails to take into account the characteristic available water capacity (AWC) of different soils or planting substrates, e.g. a soil moisture deficit of 25mm may not be serious for a plant growing in a silt loam, but may be catastrophic for the same genotype growing in a substrate analogous to coarse sand.

Table 6.25 Typical AWC of Various Planting Substrates (From Winter 1974)

Substrate	AWC as mm/0.3m profile
Coarse Sand	25
Sand	45
Clay	51
Silt Loam	57
Very Fine Silt	69

As can be seen from Table 6.25 the range of AWC associated with even agricultural soils is considerable. Substrates upon which landscape activities are carried out may sometimes fall outside this range, although even seemingly drought prone amenity substrates may prove to have relatively high AWC's as has been shown for crushed brick rubble by Blunt (1982).

A clearer picture of likely soil moisture stress can be gained by subtracting values for soil moisture deficit from the available water capacity of a soil and comparing the result with the scale in Table 6.26

Table 6.26 Classes of Drought Proneness Derived from Available Water Content of the Profile and Soil Moisture Deficit (From MAFF 1974)

AWC - SMD in mm

AWC - SMD in mm	Class
	non droughty
+ 50	
	slightly droughty
0	
	moderately droughty
- 50	
	very droughty

Due to the difficulties involved in obtaining AWC values for typical landscape as opposed to agricultural soils and the need for the user to accurately assess his soil type, this improved means of predicting likely soil moisture stress at the planting site has not been incorporated into Climatebase.

Despite the obvious deficiencies, a zonation using the parameter of soil moisture deficit does provide a framework upon which a comparison of the AWC of site substrates can be made. Factors such as weed competition dramatically affect AWC, and are discussed together with the plants response to soil moisture in 7.4 .

Soil moisture data was extracted from MAFF Bulletin 30 (Smith 1976b) for the 67 reference areas of Climatebase. Values for the five altitudinal levels in each reference area were calculated by using the lapse rate constants in Table 6.27

Table 6.27 Decrease in Maximum Summer Moisture Deficit with Altitude (From Smith 1976b)

Area		mm per 75m
Northern England, Midlands and Wales	a	16.9
Southern England	b	20.6
South Western England	c	24.3

The resulting data is summarised in Table 6.28.

Table 6.28 Soil Moisture Deficit Data and Resulting Soil Moisture Stress Zones (data derived from Smith 1976b)

Reference Area		0-75m	75-150m	150-225m	225-300m	300-375m	Resulting Soil Moisture Stress Zones:				
1n	a	86.8	69.9	-	-	-	4	3	-	-	-
1s	a	86.6	69.7	-	-	-	4	3	-	-	-
2	a	86.6	69.7	52.8	35.9	19.0	4	3	3	2	1
3	a	68.4	51.5	34.6	17.7	0.8	3	3	2	1	1
4	a	106.8	89.9	73.0	56.1	39.2	4	4	3	3	2
5	a	95.7	78.8	61.9	45.0	28.1	4	3	3	2	2
6	a	78.8	61.9	45.0	28.1	11.2	4	4	3	2	2
7	a	97.9	81.0	64.1	47.2	30.3	4	4	3	2	2
8	a	76.1	59.2	42.3	25.4	8.5	3	3	2	2	1
9	a	80.8	63.9	47.0	-	-	4	3	2	-	-
10	a	102.3	85.4	68.5	51.6	34.7	4	4	3	3	2
11	a	101.1	84.2	67.3	50.4	33.5	4	4	3	3	2
12	a	93.3	76.4	59.5	-	-	4	3	3	-	-
13	a	96.8	79.9	63.0	-	-	4	3	3	-	-
14	a	91.3	74.4	57.5	40.6	23.7	4	3	3	2	2
15w	a	102.2	85.3	68.4	51.5	34.6	4	4	3	3	2
15e	a	106.3	89.4	72.5	-	-	4	4	3	-	-
16	a	113.6	96.7	79.8	-	-	5	4	4	-	-
17w	a	112.0	95.1	-	-	-	5	4	-	-	-
17e	a	102.2	85.3	-	-	-	4	4	-	-	-
18n	a	108.4	91.5	74.6	57.7	40.8	4	4	3	3	2
18s	a	-	97.8	80.9	64.0	47.1	-	4	4	3	2
19	a	113.1	96.2	79.3	62.4	45.5	5	4	3	3	2

20	a	114.2	97.3	80.4	-	-	5	4	4	-	-
21	a	113.5	96.6	79.7	-	-	5	4	3	-	-
22w	a	120.3	103.4	86.5	-	-	5	4	4	-	-
22e	a	117.0	100.1	83.2	-	-	5	4	4	-	-
23	a	108.5	-	-	-	-	4	-	-	-	-
24	a	112.0	-	-	-	-	5	-	-	-	-
25n	a	108.3	91.4	74.5	57.6	-	4	4	3	3	-
25s	a	97.5	80.6	63.7	46.8	29.9	4	4	3	2	2
26	a	115.9	99.0	82.1	65.2	-	5	4	4	3	-
27	b	122.5	101.9	81.3	-	-	5	4	4	-	-
28	b	118.2	97.6	77.0	-	-	5	4	3	-	-
29	b	117.2	96.6	76.0	-	-	5	4	3	-	-
30	c	107.7	83.4	-	-	-	4	4	3	-	-
31n	b	127.5	106.9	86.3	-	-	5	4	4	-	-
31s	b	121.5	100.9	80.3	59.7	-	5	4	4	3	-
32	b	119.2	98.6	78.0	-	-	5	4	3	-	-
33w	b	127.7	107.1	86.5	-	-	5	4	4	-	-
33e	b	117.7	97.1	76.5	-	-	5	4	3	-	-
34	b	118.7	98.1	77.5	-	-	5	4	3	-	-
35	c	119.6	95.3	71.0	46.7	-	5	4	3	2	-
36	b	126.5	105.9	85.3	64.7	-	5	4	4	3	-
37n	b	111.4	90.8	-	-	-	5	4	-	-	-
37s	b	110.4	89.8	-	-	-	5	4	-	-	-
38n	b	115.6	95.0	74.4	-	-	5	4	3	-	-
38s	b	111.1	90.5	-	-	-	5	4	-	-	-
39w	b	120.9	100.3	79.7	-	-	5	4	3	-	-
39e	b	115.2	94.6	-	-	-	5	4	-	-	-
40	c	105.1	80.8	56.5	-	-	4	4	3	-	-
41	c	101.2	76.9	52.6	-	-	4	3	3	-	-

42	c	98.5	74.2	49.9	25.6	1.3	4	3	2	2	1
43n	c	106.5	82.2	57.9	33.6	9.3	4	4	3	2	1
43s	c	97.4	73.1	48.8	24.5		4	3	2	2	-
44	c	120.6	96.3	72.0	47.7	23.4	5	4	3	2	2
45w	c	121.9	97.6	73.3	49.0	-	5	4	3	2	-
45e	c	114.3	90.0	65.7	-	-	5	4	3	-	-
46	c	105.5	81.2	-	-	-	4	4	-	-	-
47	a	81.4	64.5	47.6	30.7	-	4	3	2	2	-
48n	a	60.1	43.2	26.3	9.4	0.0	3	2	2	1	1
48s	a	84.7	67.8	50.9	34.0	17.1	4	3	3	2	1
49n	a	111.2	94.3	77.4	60.5	43.6	5	4	3	3	2
49s	a	115.4	98.5	81.6	74.7	57.8	5	4	4	3	3
50	a	76.7	59.8	42.9	26.0	9.1	3	3	2	2	1
51	a	69.7	52.8	35.9	19.0	2.1	3	3	2	1	1
52	a	80.1	63.2	46.3	29.4	12.5	4	3	2	2	1
L	b	121.5	100.9	80.3	-	-	5	4	4	-	-

L = London

Mean of data (excluding London = 66.5)

Five soil moisture deficit zones were created around the mean of the data as shown in Table 6.29

Table 6.29 Soil Moisture Stress Zones of Climatebase

	Summer Soil Moisture Deficit (mm)	Soil Moisture Stress Zone
	<20	1
increasing	20-50	2
dryness	50-80	3
	80-110	4
	>110	5

7. The Development of Plantbase

Plantbase represents the bulk of the Hortbase information retrieval system, its function being to supply information on the characteristics of decorative plants.

The components of Climatebase have been discussed in the preceeding section, and one of the important features of Plantbase is that it defines aspects of plant performance in terms of the climatic zones of the former, i.e it facilitates a prediction of plant success for any taxon contained within the database for any planting site in England and Wales.

Plantbase is an open ended system in that extra data (plant records) can be added as desired. Plantbase currently contains data on over 200 important landscape plants.

The range of information documented in plantbase is summarised in Table 7.1 in the order discussed in the proceeding sections.

The most important sources of decorative plant information have been identified in the introductory chapters. Plantbase has with the exception of the Herbaria tapped all of these to a greater or lesser extent.

Despite the seemingly exhaustive documentation of

Table 7.1 Content of Plantbase Grouped by Subject Area

Subject Area	Specific Topics	Plantbase Name
Plantbase Identifiers		
	Serial Number	snum
	Plant Name	name
Plant Response to Climatic Factors		
Hardiness	Coldest DD below 0 centigrade zone in which plant can be considered hardy	hardiness
Solar Radiation	Minimum solar radiation zone in which plant can flower satisfactorily when in full sun, i.e response to overall radiation climate	flower_sun
	Minimum solar radiation zone in which plant can flower satisfactorily in sun to light shade	flower_sun-inter
	Minimum solar radiation zone which plant can flower satisfactorily in light shade to shade	flower_inter-shade

Solar Radiation	Minimum solar radiation zone in which plant can flower satisfactorily in full shade	flower_shade
	Minimum solar radiation zone in which plant can flower satisfactorily in full sun through to full shade (i.e complete range)	flower_sun-shade
	Minimum solar radiation zone in which plant can grow satisfactorily in full sun	growth_sun
	Minimum solar radiation zone in which plant can grow satisfactorily in full sun to light shade	growth_sun-inter
	Minimum solar radiation zone in which plant can grow satisfactorily in light shade to full shade	growth_inter-shade
	Minimum solar radiation zone in which plant can grow satisfactorily in full shade	growth_shade
	Minimum solar radiation zone in which plant can grow satisfactorily in sun through to shade (i.e complete range)	growth_sun-shade

Growing Season Warmth	Minimum summer warmth necessary for satisfactory plant development	warmth_necessary
Soil Moisture Stress	Minimum soil moisture status for satisfactory growth	soil_moisture_def
Exposure	Tolerance of exposure	tol_expos
<u>Husbandry Characteristics</u>		
	Plant soil moisture requirements	water
	Plant tolerance of compacted clay substrates	tol_comp_clay
<u>Growth Substrates</u>		
	Plant tolerance of free draining aggregates	tol_fr_dr_aggr
	Plant pH requirements	ph
Miscellaneous	Plant tolerance of pollution	polu_tol
	Plant tolerance of air borne salt spray	salt_tol
	Plant tolerance of stooling and coppicing	tol_coppice

	Plant ability to self adhere to masonry	attach_mason
	Leaf fall litter characteristics	lf_fall
	Plant capacity to recover satisfactorily from vandalism	vandal_tol
Plant tolerance of Herbicides	Plant tolerance of herbicide dichlobenil applied immediately after planting	herb_pre_est_dich
	Plant tolerance of herbicide lenacil applied immediately after planting	herb_pre_est_len
	Plant tolerance of herbicide propyzamide applied immediately after planting	herb_pre_est_prop
	Plant tolerance of herbicide simazine applied immediately after planting	herb_pre_est_sim
	Plant tolerance of herbicide dichlobenil applied when established	herb_est_dich
	Plant tolerance of herbicide glyphosate applied when established	herb_est_gly

Plant tolerance of herbicide lenacil applied when established	herb_est_len
Plant tolerance of herbicide propyzamide applied when established	herb_est_prop
Plant tolerance of herbicide simazine applied when established	herb_est_sim
Plant characteristic aesthetic life - span	aesth_life
Plant characteristic maintenance demand	mainten_input
Plant ease of cultivation	cultiv_ease
Plant primary landscape function	hort_func
Maximum soil depth over perennating organs	pltng_depth
Maximum water depth plant will grow in	depth water
Limitations associated with the plants use	user_lim
Plant additional information	add_fturs

Mensuration

Expected height of mature specimens in GB	height
Expected width of mature specimens in GB	width

	Expected height after 10 years growth in GB	height_10
	Expected width after 10 years growth in GB	width_10
	Expected growth rate for woody plants in GB	growth_wood
	Expected growth rates for herbaceous plants in GB	growth_herb
	Characteristic leaf size	lf_size
	Characteristic foliage density	density
<u>Morphology and Display Characteristics</u>		
	Overall morphology of the plant i.e form	form
	Leaf shape	lf_shape
	Leaf margin	lf_margin
	Stem diameter	s_diam
	Texture of overall vegetative plant in leaf	text
	Tracery of stems in winter (for deciduous plants)	tracery
	Stem texture	s_text
	Bark texture	b_text
	Leaf texture	lf_text

Stem colour	s_col
Bark colour	b_col
Leaf colour in Spring	lf_col_spr
Leaf colour in Summer	lf_col_sum
Leaf colour in Autumn	lf_col_aut
Leaf colour in Winter	lf_col_win
Leaf colour ventral surface	lf_col_vent
Flower colour	fl_col
Fruit colour	fr_col
Tonal range and pattern of distribution of stem colour	s_col_qual
Tonal range and pattern of distribution of bark colour	b_col_qual
Tonal range and pattern of distribution of leaf colour in Spring	lf_col_qual_spr
Tonal range and pattern of distribution of leaf colour in Summer	lf_col_qual_sum

Tonal range and pattern of distribution of leaf colour in Autumn	lf_col_qual_aut
Tonal range and pattern of distribution of leaf colour in Winter	lf_col_qual_win
Tonal range and pattern of distribution of ventral leaf colour	lf_col_qual_vent
Tonal range and pattern of distribution of flower colour	fl_col_qual
Tonal range and pattern of distribution of fruit colour	fr_col_qual
Leaf scent intensity when handled	lf_scent
Flower scent intensity	fl_scent
Stem reflectivity e.g shiny or dull	s_reflect
Leaf reflectivity	lf_reflect
Month in which flowering commences	fl_period
Duration of flowering period	fl_duration
Persistance of fruit in an attractive form	fr_persist

Visual quality of overall morphology	form_intens
Overall quality of stems in terms of contribution to the landscape	s_intens
Overall quality of bark in terms of contribution to the landscape	b_intens
Spring leaf quality in terms of overall contribution to the landscape	lf_intens_spr
Summer leaf quality in terms of overall contribution to the landscape	lf_intens_sum
Autumn leaf quality in terms of overall contribution to the landscape	lf_intens_aut
Winter leaf quality in terms of overall contribution to the landscape	lf_intens_win
Average leaf quality over the period when foliage is present	lf_intens_av
Flower quality in terms of overall contribution to the landscape	fl_intens

Fruit quality in terms of contribution to the landscape	fr_intens
Overall plant display contribution to the landscape for the 12 months of the year	m_eff
The mean of the yearly contribution to the landscape	m_eff_av
Overall plant quality in terms of contribution to landscape in January	jan_eff
Overall plant quality in terms of contribution to landscape in February	feb_eff
Overall plant quality in terms of contribution to landscape in March	mar_eff
Overall plant quality in terms of contribution to landscape in April	apr_eff
Overall plant quality in terms of contribution to landscape in May	may_eff
Overall plant quality in terms of contribution to landscape in June	jun_eff

Overall plant quality in terms of contribution to landscape in July	jul_eff
Overall plant quality in terms of contribution to landscape in August	aug_eff
Overall plant quality in terms of contribution to landscape in September	sept_eff
Overall plant quality in terms of contribution to landscape in October	oct_eff
Overall plant quality in terms of contribution to landscape in November	nov_eff
Overall plant quality in terms of contribution to landscape in December	dec_eff
Leaf persistance i.e evergreen or deciduous	lf_persist
Life cycle of plant	life_cyc
Indigenous or naturalised in GB	indig_nat
Plant taxonomy	taxon

decorative plant characteristics in the literature, no quantified information is available for some of the topics under consideration. For example critical assessment of display components, dates for the commencement and duration of display, tolerance of environmental conditions such as soil compaction, and flowering and vegetative growth in response to shade. This "information vacuum" is especially serious in topics of contemporary interest, for example plant tolerance of soil applied herbicides.

Compared with other areas of science and technology which similarly grew from amateur beginnings, those involved in decorative plant studies have proved reluctant to embrace a quantified approach to understanding and recording plant performance. It is curious that with few exceptions e.g Shaw (1978) most people within decorative horticulture do not seem to have recognised that our knowledge is deficient.

In order to overcome some of the difficulties posed by the absence of suitable data, the author has over a period of two years collected information from a wide range of private and public collections on a season by season basis. The location and climatic characteristics (as defined by Climatebase) of these sites are summarised in Table 7.2.

Observations of plant performance made over such a short period of time, may not always accurately reflect the typical response of a taxon and the influence of atypical environmental factors prevailing at the time of assessment have, where recognised, been taken into account when analysing such data. In order to obtain sufficient data to quantify plant response to climate and estimate the influence of certain relevant microclimatic phenomena it was essential to abstract information from a wide cross section of sites throughout England and Wales. This entailed the identification of a large number of representative sites, which were in turn either visited by the author or surveyed via a questionnaire.

The following questionnaire surveys have been employed;

a) A survey of plant performance in response to climate and microclimate, aimed at plantsmen or the professional horticulturalists of Institutional Collections.
b) A Survey of open ground nursery stock producers regarding plant response to residual herbicides and transplanting ease of tree species at various stages of maturity.

The plantsman survey involved over 300 collections and produced a return of 47.7%, corresponding to 143 correctly completed questionnaires. (See Table 7.2 for locations). Two formats (a & b) were used in this survey in recognition of the different cultivated floras that predominate in different regions of England and

Wales. More specific details of this questionnaire are given in section 7.2.1 .

The nurserymans questionnaire was carried out with the assistance of the Joint Committee for the Landscape Industries, and out of the 35 despatched 16 correctly completed forms were returned (45.7%). Specimen copies of all 3 questionnaires are included in the Appendices.

Table 7.2 Sources of Information for Plantbase: Living Collections Investigated

(Data Derived from Climatebase)

Name and Location:	Questionnaire Format	Reference Area	Altitude	Winter Cold Zone (Average Winter)	Winter Cold Zone (Extreme Winter)	Solar Radiation Zone	Summer Warmth Zone	Soil Moisture Stress Zone
Abbotsbury Dorset	B	45e	0-75	15.0	13.0	4.0	4.0	5.0
Abbots Ripon Norfolk	A	28	0-75	11.0	7.0	3.0	5.0	5.0
Aberswyth Botanic Gardens	B	50	0-75	15.0	14.0	3.0	3.0	3.0
Algars Manor Gloucs	A	30	0-75	12.0	10.0	3.0	6.0	4.0
Andrews Corner Devon	B	43n	300-375	11.0	7.0	3.0	2.0	1.0
Barkby Hall Leics	A	22w	0-75	11.0	7.0	3.0	5.0	5.0
Barnsley House Gloucs	A	26	75-150	11.0	7.0	3.0	5.0	4.0
Barretts Lane Notts	A	16	0-75	11.0	8.0	3.0	5.0	5.0

Bath Botanic Garden, Avon	Visit	30	0-75	12.0	10.0	3.0	6.0	4.0
Bell Cottage Cheshire	A	14	0-75	12.0	8.0	3.0	5.0	4.0
Beares Suffolk	A	29	0-75	11.0	7.0	3.0	5.0	5.0
Blickling Hall Norfolk	A	24	0-75	11.0	7.0	3.0	5.0	5.0
Bodnant Gwynedd	B/Visit	48n	75-150	13.0	10.0	2.0	4.0	4.0
Bogfarm Kent	A	39w	75-150	11.0	6.0	4.0	5.0	4.0
Bridgemere Nurseries Cheshire	N	14	75-150	11.0	8.0	2.0	4.0	3.0
Bristol Botanic Gardens, Avon	B	30	75-150	11.0	8.0	3.0	5.0	4.0
Broadland House Hants	A	31s	75-150	11.0	7.0	3.0	5.0	4.0
The Bungalow Northumberland	A/ Visit	15	0-75	11.0	8.0	2.0	2.0	4.0
Burford House Worcs	A/ Visit	18s	75-150	8.0	4.0	3.0	4.0	4.0

Byworth Edge Sussex	A	37n	75-150	11.0	6.0	3.0	5.0	4.0
Cambridge Botanic Garden	A/ Visit	28	0-75	11.0	7.0	3.0	5.0	5.0
Canford London	A	L	75-150	13.0	8.0	3.0	5.0	4.0
Carrog Dyfed	B	50	0-75	15.0	14.0	3.0	4.0	3.0
Castle Drogo Devon	B	43n	225-300	11.0	8.0	3.0	3.0	2.0
Catchfrench Derbyshire	A	15e	75-150	10.0	6.0	2.0	4.0	4.0
Cefn Bere Gywnedd	A	48n	0-75	13.0	11.0	2.0	4.0	5.0
Chelsea Physic Garden London	A	L	0-75	14.0	10.0	3.0	6.0	5.0
The Chestnuts Gloucs	A	30	75-150	11.0	8.0	3.0	5.0	4.0
Cleaver Square London	A	L	0-75	14.0	10.0	3.0	6.0	5.0
Coates Manor Sussex	A	46	0-75	13.0	11.0	4.0	5.0	4.0

Colt House Notts	A	16	0-75	11.0	8.0	3.0	5.0	5.0
Combe Head Devon	B	44	150-225	12.0	10.0	3.0	4.0	3.0
Cotehele Cornwall	B	42	0-75	14.0	14.0	4.0	5.0	4.0
Court Farm Oxford	A	31n	0-75	12.0	9.0	3.0	6.0	5.0
Crittenden Kent	A	39w	0-75	12.0	8.0	4.0	6.0	5.0
The Croft House Gloucs	A	26	75-150	11.0	7.0	3.0	5.0	4.0
The Dairy House Shrop	A	19	75-150	11.0	7.0	2.0	4.0	4.0
Darley House Derbyshire	A	10	75-150	7.0	4.0	2.0	4.0	4.0
Derbyshire College of Agriculture	A	15e	75-150	10.0	6.0	2.0	4.0	4.0
The Dingle Powis	A	18n	150-225	12.0	8.0	2.0	4.0	4.0
Docwras Hall Cambridge	A	29	0-75	11.0	7.0	3.0	5.0	5.0

University of Edinburgh	A	(1n)	75-150	12.0	9.0	2.0	2.0	3.0
Edinburgh Botanic Garden	Visit	(1n)	0-75	14.0	11.0	2.0	2.0	4.0
34 Elm Avenue Herts	A	33w	75-150	11.0	7.0	3.0	5.0	4.0
Elm Green Farm House, Suffolk	A	29	75-150	10.0	5.0	3.0	4.0	4.0
Emmetts Kent	A	38n	150-225	10.0	5.0	3.0	4.0	3.0
Fairway Lodge Surrey	A	32	0-75	12.0	9.0	3.0	6.0	5.0
Farall Gardens Sussex	A	37n	75-150	11.0	6.0	3.0	5.0	4.0
Felbrigg Hall Norfolk	A	24	0-75	13.0	9.0	3.0	4.5	5.0
Fernwood Devon	B	45w	75-150	12.0	10.0	4.0	4.0	4.0
FFrwdgrech Powis	A	49s	150-225	8.0	5.0	2.0	4.0	4.0
Forde Abbey Somerset	B	35	75-150	12.0	10.0	3.0	5.0	4.0

Foxgrove Berks	A	31n	75-150	11.0	7.0	3.0	5.0	4.0
Frognall London	A	L	75-150	13.0	8.0	3.0	5.0	4.0
Garden House Devon	B	43n	150-225	12.0	10.0	3.0	4.0	3.0
Glendurgan Cornwall	B	40	0-75	16.0	16.0	4.0	4.0	4.0
Goatcher and Son, Sussex	N	38s	0-75	13.0	10.0	4.0	5.0	5.0
The Grange Kent	A	38n	75-150	11.0	6.0	4.0	5.0	4.0
Great Comp Kent	A	39w	75-150	11.0	6.0	4.0	5.0	5.0
Great Dixter Sussex	A/ Visit	38n	0-75	13.0	9.0	4.0	5.0	5.0
The Grove London	A	L	75-150	13.0	8.0	3.0	5.0	4.0
Gunby Hall Lincs	A	17e	0-75	11.0	8.0	3.0	4.0	4.0
Hadlow College Kent	A	39w	0-75	12.0	8.0	4.0	6.0	5.0

Hadspen House Somerset	B/ Visit	35	75-150	13.0	10.0	3.0	5.0	4.0
Hardwick Hall Derbyshire	A	16	150-225	10.0	6.0	2.0	4.0	4.0
Harlow Car Yorks	Visit	12	75-150	10.0	6.0	2.0	4.0	3.0
Haytor Warwicks	A	21	0-75	11.0	8.0	3.0	5.0	5.0
The Heath Yorks	A	11	75-150	10.0	7.0	2.0	4.0	4.0
Hidcote Gloucs	Visit	26	75-150	11.0	7.0	3.0	5.0	4.0
Hidcote Vale Gloucs	A	26	75-150	11.0	7.0	3.0	5.0	4.0
Higher Knowle Devon	B	43n	75-150	13.0	11.0	3.0	4.0	4.0
Highbury Dorset	B	36	0-75	13.0	10.0	4.0	6.0	5.0
Hillier Arboretum Hants	Visit	31s	0-75	12.0	9.0	4.0	6.0	5.0
Howick Northumberland	A/ Visit	1s	0-75	13.0	10.0	2.0	2.0	4.0

Hurst Mill Hants	A	31s	0-75	9.0	6.0	4.0	6.0	5.0
Hyde Hall Essex	A	33e	0-75	11.0	8.0	3.0	5.0	5.0
Italian Gardens Northumberland	A	1s	0-75	13.0	10.0	2.0	2.0	4.0
J H Jones Lancs	N	9	0-75	13.0	11.0	3.0	3.0	4.0
Juniper Hill Bucks	A	27	75-150	10.0	5.0	3.0	5.0	4.0
RBG Kew London	Visit	L	0-75	14.0	10.0	3.0	6.0	5.0
Kiftsgate Court, Gloucs	A/ Visit	26	150-225	11.0	7.0	2.0	4.0	3.0
Killerton Devon	B	45w	75-150	13.0	11.0	4.5	4.0	4.0
Knightshayes Devon	B/ Visit	35	75-150	13.0	11.0	3.0	5.0	4.0
Knights Nurseries Sussex	N	38s	0-75	13.0	10.0	4.0	5.0	5.0
Knoll Gardens Dorset	B/ Visit	46	0-75	13.0	11.0	4.0	5.0	4.0

Kypp Cottage Kent	A	39w	0-75	12.0	8.0	4.0	6.0	5.0
The Lammas Gloucs	A	30	75-150	11.0	8.0	3.0	5.0	4.0
The Level Gloucs	A	25s	0-75	12.0	10.0	3.0	5.0	4.0
Lime Close Oxon	A	31n	150-225	10.0	5.0	3.0	4.0	4.0
Little Chesterford Manor, Essex	A	29	0-75	11.0	7.0	3.0	5.0	5.0
Little Norton Mill Nursery Somerset	B	35	0-75	13.0	11.0	3.0	5.0	5.0
191 Liverpool Road South Merseyside	A	9	0-75	11.0	9.0	3.0	4.0	4.0
Long Close Leics	A	15e	150-225	10.0	5.0	2.0	4.0	3.0
Lower Hall Salop	A	19	0-75	8.0	5.0	3.0	5.0	5.0
The Malt House Surrey	A	32	0-75	12.0	9.0	3.0	6.0	5.0

Martins Gloucs	A	30	75-150	11.0	8.0	3.0	5.0	4.0
Marwood Hill Devon	B/ Visit	44	75-150	10.0	9.0	4.0	4.0	4.0
Mawley Hall Salop	A	19	75-150	11.0	7.0	2.0	4.0	4.0
The Meadows Warwicks	A	20	75-150	11.0	7.0	2.0	5.0	4.0
The Merchant House, Norfolk	A	28	0-75	11.0	7.0	3.0	5.0	5.0
Merrist Wood College Surrey	A	32	0-75	12.0	9.0	3.0	6.0	5.0
Milngate Cheshire	A	14	75-150	11.0	8.0	2.0	4.0	3.0
Milton Lodge Somerset	B	35	75-150	12.0	10.0	3.0	5.0	4.0
Miniquiers Dorset	B	46	0-75	13.0	11.0	4.0	5.0	4.0
The Moorings Surrey	A	37n	0-75	12.0	8.0	4.0	5.0	5.0
Moreley and Sons, Cheshire	N	14	75-150	11.0	8.0	2.0	4.0	3.0

Moulin Huet Dorset	B	36	75-150	11.0	8.0	3.0	5.0	4.0
Ness BG Merseyside	B/ Visit	9	0-75	13.0	11.0	3.0	3.0	4.0
Notcutts Nurseries Suffolk	N	29	0-75	11.0	7.0	3.0	5.0	5.0
North Cove Hotel, Suffolk	A	29	0-75	11.0	7.0	3.0	5.0	5.0
Northreps Cottage, Hants	A	46	0-75	11.0	7.0	3.0	5.0	5.0
210 Nottingham Road, Notts	A	15e	75-150	11.0	7.0	2.0	4.0	4.0
The Old Crown Bucks	A	31n	75-150	11.0	7.0	3.0	5.0	4.0
The Old Rectory Burghfield Berks	A	31n	75-150	11.0	7.0	3.0	5.0	4.0
The Old Rectory Farnborough Berks	A	31n	225-300	10.0	4.0	3.0	3.0	3.0
The Old Rectory Leics	A	22e	75-150	10.0	6.0	3.0	4.0	4.0

Orchard House Somerset	B	30	0-75	12.0	10.0	3.0	6.0	4.0
Pant Yr holiad Dyfed	B	50	150-225	12.0	9.0	3.0	3.0	2.0
Penllyn Castle Glams	B	52	75-150	13.0	10.0	3.0	4.0	3.0
Penn Cheshire	A	14	75-150	11.0	8.0	2.0	4.0	3.0
Pennells Nurseries Lincs	N	17e	0-75	11.0	8.0	3.0	4.0	4.0
Pennine Nurseries Yorks	N	11	150-225	9.0	6.0	2.0	3.0	3.0
Pennington Chase Hants	B	46	0-75	15.0	13.0	4.0	5.0	4.0
Penraut Ffynon Dyfed	B	50	75-150	12.0	10.0	3.0	4.0	3.0
Powis Castle Powys	A	18n	75-150	13.0	8.0	3.0	4.0	4.0
Putsborough Manor Devon	B	44	0-75	16.0	15.0	4.0	4.0	5.0
Rawnthorpe Hall Norfolk	A	24	0-75	8.0	4.0	3.0	4.0	5.0

Renishaw Hall Yorks	A	16	75-150	10.0	7.0	2.0	4.0	4.0
Restharrow Devon	B	45w	75-150	12.0	10.0	4.0	4.0	4.0
Resthill Farm Oxon	A	26	75-150	11.0	7.0	3.0	5.0	4.0
Rockfarm Kent	A	39w	0-75	12.0	9.0	4.0	6.0	5.0
Rockshiel Gwent	A	25s	150-225	11.0	7.0	3.0	4.0	3.0
R V Roger Yorks	N	7	0-75	12.0	9.0	2.0	3.0	4.0
Rooksnest Berks	A	31n	150-225	10.0	5.0	3.0	4.0	4.0
Rosemoor Devon	B	41	75-150	13.0	12.0	3.0	4.0	3.0
Russets Dorset	B	45e	75-150	12.0	10.0	4.0	4.0	4.0
Saling Hall Essex	A	29	75-150	10.0	5.0	3.0	4.0	4.0
Saltram Devon	B	42	0-75	14.0	14.0	4.0	5.0	4.0

Scotts Nurseries Somerset	N	35	0-75	13.0	11.0	3.0	5.0	5.0
Sharpitor Devon	B	43s	75-150	15.0	14.0	4.0	3.0	3.0
Sheffield BG Yorks	A	10	75-150	10.0	7.0	2.0	4.0	4.0
Silver Birches Yorks	A	12	150-225	9.0	5.0	2.0	3.0	3.0
Springfield Barn Avon	A/ Visit	30	0-75	12.0	10.0	3.0	6.0	4.0
Spring Lodge Durham	A	4	150-225	9.0	5.0	2.0	3.0	3.0
South Collingham Manor Notts	A	16	0-75	11.0	8.0	3.0	5.0	5.0
St Annes Manor Notts	A	16	0-75	11.0	8.0	3.0	5.0	5.0
Stone Cottage Leics	A	22e	75-150	10.0	6.0	3.0	4.0	4.0
Stretton Hall Staffs	A	19	75-150	11.0	7.0	2.0	4.0	4.0
Sunte House Sussex	A	38n	75-150	11.0	6.0	4.0	5.0	4.0

Swallow Hayes Salop	A	19	75-150	10.0	6.0	2.0	4.0	4.0
Tatton Park Cheshire	A	14	0-75	12.0	9.0	3.0	5.0	4.0
Telford Devel. Corp.	N	18n	75-150	11.0	7.0	3.0	4.0	4.0
Tetworth Hall Beds	A	28	0-75	11.0	7.0	3.0	5.0	5.0
Tilty Hill Farm Essex	A	29	75-150	10.0	5.0	3.0	4.0	4.0
Torrymyndd Farm Gwent	A	25s	150-225	11.0	7.0	3.0	4.0	3.0
Trengwainton Cornwall	B	40	0-75	16.0	16.0	4.0	4.0	4.0
Trewithen Cornwall	B	40	150-225	13.0	11.0	3.0	4.0	3.0
Tynewydd Powys	A	49n	150-225	11.0	7.0	2.0	3.0	3.0
Vann Surrey	A	32	0-75	12.0	9.0	3.0	6.0	5.0

Venns Suffolk	A	29	0-75	11.0	7.0	3.0	5.0	5.0
Wallington Hall Northumberland	Visit	2	75-150	10.0	6.0	1.0	3.0	3.0
Waterers Nurseries Surrey	N	32	0-75	12.0	9.0	3.0	6.0	5.0
Wayford Manor Somerset	B	35	75-150	12.0	10.0	3.0	5.0	4.0
Welsh College Agric Gywnedd	A	14	75-150	11.0	8.0	2.0	4.0	3.0
Westend House Avon	A	30	0-75	12.0	10.0	3.0	6.0	4.0
Westonbirt Arboretum Gloucs	Visit	30	150-225	11.0	7.0	3.0	4.0	3.0
Whitefarm House Oxon	A	31n	75-150	11.0	7.0	3.0	5.0	4.0
Wisley Surrey	Visit	32	0-75	12.0	9.0	3.0	6.0	5.0
Wooton House Somerset	B	35	0-75	13.0	11.0	3.0	5.0	5.0

Writtle College Essex	A	33e	0-75	11.0	8.0	3.0	5.0	5.0
Wynfield Lancs	A	9	0-75	11.0	9.0	3.0	4.0	4.0

1 = data as for Area 1s

7.1 Components of Plantbase

The two Plantbase identifiers are:

Plant Serial Number

Plantbase topic involved:

snum

Every plant recorded within Plantbase is primarily identified by a serial number. Serial number is analogous with the reference area of Climatebase. Integers between 1 and 9999 are permissible.

Plant Botanical Name

Plantbase topic involved:

name

The full binomial is used and subspecific ranking is documented in accordance with the current international nomenclature ruling. (IBPTN 1969)

A maximum of 48 letters may be used in this field.

7.2 Coldest Winter Cold Zone in which a Plant can be Considered Hardy

Plantbase topics involved:

hardiness

The hardiness responses of plants in the field are extremely complex, being based on interacting variables such as the capacity of a planting site to experience cold (latitude, longitude, altitude, and microclimate), plant tolerance of cold as determined by genotype, carbohydrate status and pre-conditioning plus accessory factors such as degree of exposure, soil moisture and nutrient levels.

Because of this, the hardiness responses of decorative plants and especially the variable responses of members of a clone within a small geographical area, have often baffled the empirical observer.

In the decorative plant literature discussion of hardiness is frequently based upon misconceptions and occassionally inaccurate recording of the "lethal" temperatures.

The Royal Horticultural Societies Surveys of frost damage sustained in the 1947-8 and 1962-3 winters (Royal Horticultural Society 1948a,b, 1964) summarise results from a large number of collections and also cite for comparison, the minimum air temperatures experienced (as recorded by the owner). Analysis reveals that with the exception of the institutionalcollections where trained staff have made the observations many of the temperature records cited are clearly meteorologically absurd. For example, within the county of Hertfordshire, the minimum temperatures recorded as having occured in the 1947-8 winter range from -3.0 to 30.0 degrees farenheit for sites at comparable altitude. Similar anomalies appear in the records for most other counties. Our knowledge of the field hardiness of decorative plants is based almost entirely on such observations. (Shaw 1978).

In light of this the need for a realistic classification of winter cold as a basis for comparison is clearly shown. In the decorative plant literature the wealth of hardiness observations are frequently distilled into six options, hardy, or not hardy in the north, hardy or not hardy in the south and finally hardy or not hardy in the south west. The author proposes that it is possible to improve upon the above classification providing that the climatic reference model against which plant hardiness is assessed is not so simple as to be incapable of reflecting the winter cold that a site can in practice experience.

Whilst the winter cold classification of Climatebase may be considered to go some way to meet this requirement it is inevitably based on a meteorologically normal distribution of winter cold and is unrepresentative during periods when extreme deviations from this expected pattern occur, as in the case of South West England in 1978-9.

Assessment of plant hardiness in the field is essentially a highly subjective judgement being based upon performance in past winters. For plants on the borderline of hardiness a concept of absolute hardiness is difficult to reconcile. In order to avoid these pitfalls, on Plantbase hardiness is assessed in relation to two defined levels of winter cold (see 6.3).

The plants capacity to avoid low temperature damage during winter months depends upon:
The timing, intensity and duration of winter cold resulting from the interaction of climatic and local site conditions and the physiological hardiness potential of the plant. The overall or macroclimatic nature of a winter is primarily determined by the nature of the prevailing circulation systems. Table 7.3 summarises typical British winter circulation patterns and the resultant cold intensity of the winter.

Table 7.3 Effect of Winter Circulation Patterns on Winter Minima

Adapted from Lamb (1964) and Manley (1975)

Circulation Type	Frequency of occurence in Britain	Effect on winter minima experienced
Cyclonic	Frequent	Relatively high minima(above freezing) cloudy, wet and windy, little or no damage to plants
Anticyclonic	Relatively frequent	Radiation frosts of varying severity, in relatively low to severe minima. Some damage to less hardy or non acclimated plants
Extreme anticyclonic	Relatively infrequent	Very low minima due to extreme radiation frosts and advective (wind) frosts. Damage even to "hardy" plants

Britains detachment from the continental landmass ensures our winters are characteristically dominated by cyclonic weather with the occasional overlay of an anticyclonic system resulting in alternating periods of relatively high and low temperatures.

Consequently, in Britain sub zero winter temperatures are largely associated with nocturnal radiation frosts. This is in contrast to continental climates where in winter the entire air mass remains around or below freezing and radiation frosts are primarily considered to be a spring and autumn phenomenon (Sydnor 1978).

Within this overall pattern certain areas of Britain can be identified as being relatively continental in character, e.g. The Western Midlands and East Anglia, whereas the western seaboard enjoys a more oceanic climate and therefore fewer extremes of temperature. Even under extreme anticyclonic conditions, winter cold differentials resulting from these macro locational effects are maintained.

Contrary to popular opinion, under the latter conditions and to some extent during all anticyclonic weather, nocturnal winter minima do not automatically drop in step with increasing latitude. The increased distance of northern districts from the cold continental air mass is frequently more than sufficient to offset the consequences of closer proximity to the pole. This is demonstrated by the performance of taxa in collections in Eastern Scotland and North East England during the winters of 1947-8, 1962-3 and 1978-9 compared with that of the same taxa in southern collections. (Royal Horticultural Society 1948a,b, 1963, 1964, Cooke 1967a,b, Lady Howick of Glendale 1974)

In the British Isles the frequent absence of a progressive drop in night minima below 0 degrees centigrade from autumn onwards typical of continental climates, may result in decorative plants whose cold acclimation processes are insufficiently advanced to tolerate the cold associated with the winters first major anticyclonic system. Given this situation even potentially "hardy plants" may be severely damaged as was evidenced by such a sequence of events in December 1981.

The inadequacy of the British climate in successfully promoting internal hardiness mechanisms (Day & Peace 1937, Waister & Gill 1979) in turn helps explain the discrepancies between the reported hardiness of some plants in Britain and the United States e.g Lagerstroemia indica.

As has been discussed at some length in 6.3.2 and 6.3.3 within the overall macroclimate, microclimate in terms of altitude, topography, vegetation and urbanisation can create extremely localised climates which experience a different range of winter cold. The degree of modification is something that has not been sufficiently appreciated by the users of decorative plants. Cox

(1979) cites the following observations of the effects of local topography on winter minima for the relatively uniform terrain of the Arnold Arboretum:

" In the arboretum, there are differences in temperatures by as much as 5.5 degrees centigrade on a clear, still very frosty night. This means that on one particularly cold night parts of the arboretum lay from zone 3-5 and a less cold one from zone 4-7."

Many inexplicable hardiness responses in the decorative plant literature can probably be traced to the operation of a localised microclimate.

The physiological hardiness potential of plants can be considered as being determined by several key factors:

a) The innate (i.e at genotype level) capacity to avoid or not avoid damage due to the presence or absence of internal hardiness mechanisms

b) The suitability of the alien environment of the planting site for realising or restricting this innate source of low temperature tolerance.

Hardiness mechanisms have developed to confer protection over the lower range of temperatures associated with a plants natural distribution. (Sakai & Weisner 1973).

Accordingly plants of tropical and sub tropical distribution normally possess little or no tolerance of sub-zero temperatures. Some plants would however seem to possess hardiness in excess of that necessary to survive in their natural enviroment e.g. Yucca gloriosa a coastal dune component of south eastern North America tolerates winter minima in Britain far below those it can possibly confront in nature.

Most woody plant species of wide latitudinal and altitudinal distribution are composed of an assemblage of ecotypes which in cultivation exhibit varying hardiness. This is particularly obvious in Britain with the genus Eucalyptus (Pryor 1976). These differential responses in the field may be derived from absolute differences in the potential of ecotypes to be hardened, or alternatively be relative, i.e. different ecotypes may all possess the same potential hardiness but require different environmental conditions to trigger acclimation.

For example Weisner (1970) found that individuals drawn from the coastal Oregon distribution of Cornus stolonifera were damaged by only a few degrees of autumn frost when grown in the field in Minnesota because their acclimation needs were not satisfied by the continental environment. However in the laboratory where its acclimation needs could be met artificially, the coastal ecotype could survive down to -196.0 degrees centigrade, the same minima incidentally, as the Minnesotan ecotypes could tolerate.

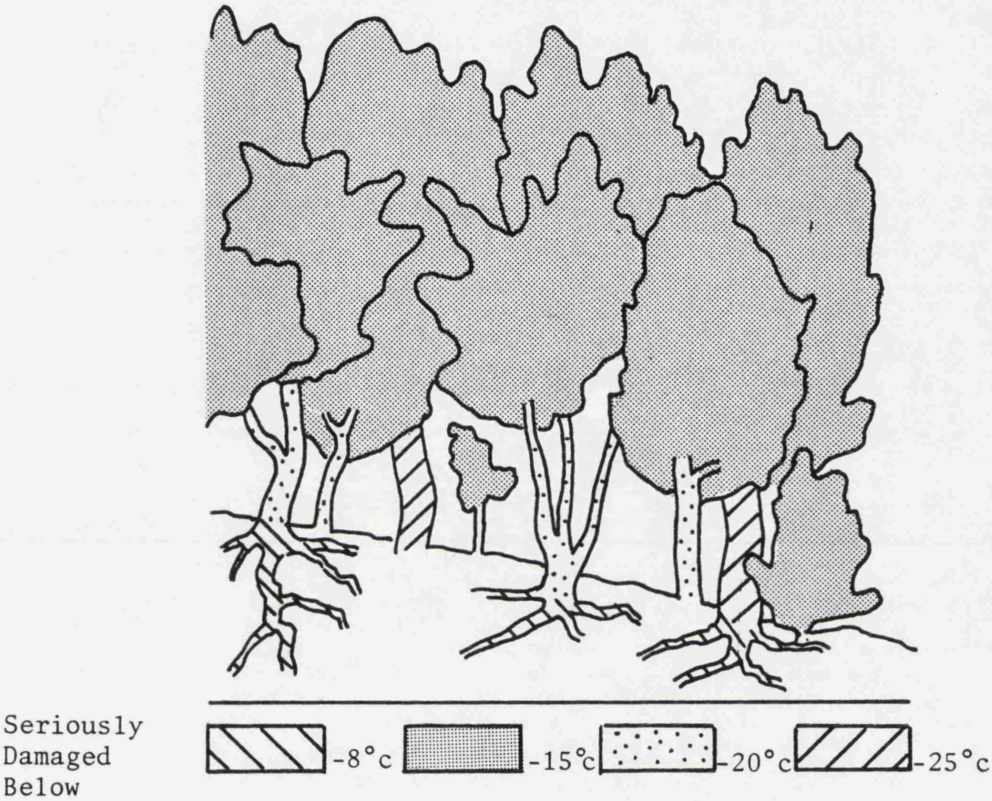
Day length and temperature during the autumn are involved in the acclimation process and as previously mentioned, in Britain the uncertain pattern of the latter during this period would seem to ensure that many species, and especially those of continental origin are unlikely to become fully acclimated.

The importance of acclimation was demonstrated in the 1978-9 winter when the normally mild south west experienced similar temperatures to the rest of England. Damage to plants in the former areas was in many cases far more severe than was experienced by the same genotypes growing in colder parts of England and Wales. It is paradoxical that in the generally mild oceanic climate of Britain many plants are prone to winter damage at temperatures above those that the plant is potentially capable of surviving.

Amongst others this response would seem to be demonstrated in Britain by species such as *Albizzia julibrissin*, *Hydrangea quercifolia*, *Lagerstroemia indica* and many of the *Eucalyptus* (Paton 1972).

Low temperatures often result in damage rather than death as the component parts of the plant frequently exhibit differential hardiness. This can often correlated with the age of the tissues, as shown for *Quercus ilex* woodland in Fig 7.1.

Fig 7.1 Differential Hardiness in Quercus ilex (From Larcher 1975)



Factors such as the soil moisture and nutrient regime (Pellet & White 1969), and carbohydrate status (Sakai 1960), also influence the hardiness response of the plant. Due to the difficulty of assessment these factors have through necessity been overlooked when arriving at plant hardiness ratings.

Actual mechanisms of low temperature resistance at the cellular level are not considered in this thesis, and reference should be made to Weisner (1970), Levitt (1972), and Sutcliffe (1977).

7.2.1 Derivation of Values for Plant Hardiness

For Plantbase plant hardiness has been assessed as the coldest winter cold zone in which a plant is likely to avoid vegetative damage beyond die back of the most distil portions of the current years growth and or in evergreens superficial leaf scorch, during the dormant season. Susceptibility to late or early frosts is documented by User Limitations (see 7.22). Damage to overwintering pre-formed floral structures is not part of this assessment and where a plant is regularly subject to this yet is vegetatively hardy the user is once again informed via User Limitations.

At the beginning of the hardiness study the woody plants considered to be of potential value in the landscape, and noted for inclusion into Plantbase were subdivided on the basis of plant hardiness into the following categories:

a) Subjects which were generally considered to be absolutely winter hardy in the context of England and Wales, i.e. there were no reliable reports of fatalities or serious injury that could be ascribed to winter cold and which rated zone 6 or lower on the Arnold Arboretum Hardiness Map (Rehder 1951). This group is the largest numerically and presents no difficulties to the quantification of hardiness as members are automatically ascribed the coldest winter cold rating as being hardy anywhere in England and Wales.

b) Subjects which can be considered to be hardy in most locations in England and Wales although are likely to suffer some damage in certain locations in 10 year extreme winters.

c) Subjects which are subject to damage in many locations in England and Wales in response to the winter conditions defined by the 10 year extreme. These genotypes show the most variable hardiness response as in many locations they may escape damage for years whilst the average winters of Climatebase prevail, and may even gain acceptance as hardy only to be killed by a 10 year extreme winter, e.g Ceanothus and Hebe cultivars. In the context of plants suitable for use in the landscape this group is the smallest of the three.

As a first step towards quantifying the field hardiness of members of the latter 2 groups, collections growing such plants were identified for every county of England and Wales. The macro and microclimate of these collections were assessed using Climatebase, allowing them to be used as quantifiable reference points against which to compare the hardiness performance of plants. These sites together with their climatic breakdown are listed in Table 7.2.

In order to extract information from as many reference collections as possible a questionnaire survey was adopted as the main form of information collection, although site visits were preferred whenever possible.

Each questionnaire contained a list of taxa on which information was requested.

Two different questionnaire formats were used in recognition of the breadth of climatic conditions associated with the collections, which in turn results in very different garden floras. Questionnaire B was designed to cover collections in South Western England and Wales, whilst questionnaire A dealt with the remaining regions. Although Plantbase is primarily orientated towards the use of plants in public and institutional landscapes, garden sites were chosen for the questionnaire surveys on the premise that within these it could for the most part be assumed that cultivation and husbandry would be such that the influence of unknown factors such as weed competition, or adverse soil conditions would not be responsible for unsatisfactory plant performance, and the influence of climatic phenomena would be more clearly demonstrated.

The questionnaire aimed to structure the respondent into recording the microclimate of the planting site and the plants hardiness performance in response to this location by working through a series of multiple choice boxes.

As the winter cold zone of each collection is known from Climatebase, following analysis of the survey data, a hardiness rating has been arrived at for each of the plants in the questionnaire. This rating represents a prediction of the coldest "winter cold" zone in which it is unlikely to experience damage in excess of the criteria suggested earlier in this section.

The subjects whose hardiness has been investigated in this manner and the resulting hardiness ratings are summarised in Table 7.4.

Some evergreen taxa are susceptable to winter dehydration injury, and when subjected to exposure and sub zero conditions are damaged at temperatures above those necessary to illicit the same response in the absence of exposure.

The effects of exposure have not been included in the assessment of hardiness summarised in Table 7.4, and to counter this deficiency, the hardiness ratings of susceptable genotypes are qualified by a statement in User Limitations.

Although the hardiness ratings in Table 7.4 are primarily based on the authors surveys, the observations and research of previous authors have also been taken into account (Balfour 1941, Royal Horticultural Society 1948 a,b, 1963, 1964, Rehder 1951, Crosby 1964, Hyams 1964, Barnard 1967a,b,c, Bean 1973-1980, Beckett 1980a,b)

Table 7.4 Survey Derived Hardiness Ratings for Plants Considered to be Susceptible to Damage in a 10 Year Extreme Winter

Plant Name	Plant Listed in Questionnaire	Plant Hardiness Ratings
Abelia grandiflora	a and b	8.0
Abelia floribunda	b	12.0
Abutilon megapotamicum	b	14.0
Abutilon x suntense	a and b	19.0
Abutilon vitifolium	b	12.0
Acacia baileyana	b	14.0
Acacia dealbata	b	11.0
Acacia pravissima	b	10.0
Acacia riceana	b	11.0
Acer lobelli	a	-
Aesculus indica	a	-
" neglecta 'Erythroblastos'	a	-
Akebia quinata	b	-
Akebia trifoliata	a	-
Albizia julibrissin 'Rosea'	a	7.0
Arbutus x andrachnoides	a and b	9.0
Arbutus menziesii	a and b	9.0
Arbutus unedo	a	8.0
Arundinaria anceps	a	7.0
Artemisia arborescens	b	12.0
Azara microphylla	a	7.0
Azara microphylla'Variegata'	b	9.0

Berberidopsis corallina	a and b	9.0
Berberis valdiviana	a	8.0
Billardia longiflora	b	11.0
Buddleia colvilei 'Kewensis'	a and b	9.0
Buddleia fallowiniana	a	8.0
Buddleia globosa	a	8.0
Caesalpinia japonica	a	7.0
Callistemon citrinus	b	13.0
Callistemon rigidus	b	12.0
Callistemon subulatus	b	10.0
Camellia reticulata & cvs	b	9.0
Campsis 'Mme. Galen'	b	7.0
Carpenteria californica	a	8.0
Caryopteris clandonensis	a	6.0
Catalpa bignonoides	a	-
Catalpa fargesii	a	-
Catalpa speciosus	a	-
Ceanothus 'Burkwoodii'	a and b	9.0
Ceanothus 'Cascade'	a and b	9.0
Ceanothus 'Edinburgh'	a	10.0
Ceanothus 'Gloire de Versaille'	a	8.0
Ceanothus 'Henri Defosse'	a	8.0
Ceanothus impressus	a and b	11.0
Ceanothus lobbianus	b	12.0
Ceanothus papillosus	b	12.0
Ceanothus thyrsiflorus	a	8.0
Ceanothus x veitchianus	a and b	10.0
Cedrus deodara	a	5.0
Cephalotaxus harringtoniana	a	5.0

Ceratostigma willmottianum	a	5.0[1]
Cercis siliquastrum	a	6.0
Cercidiphylum japonicum	a and b	-
Cestrum parqui	a	8.0[1]
Chimonanthus praecox	a and b	-
Chionanthus retusus	a and b	-
Chionanthus virginicus	a and b	-
Chusquea couleou	a	6.0
Cistus x aguilari	b	10.0
Cistus x corbariensis	a and b	8.0
Cistus x cyprius	a	8.0
Cistus ladanifer	a and b	10.0
Cistus laurifolius	a	7.0
Cistus purpureus	b	12. 0
Cistus 'Silver Pink'	b	10.0
Clematis armandii	a	9.0
Clematis cirrhosa balearica	a and b	9.0
Clerodendron bungei	a	9.0
Clerodendron trichotomum	a	-
Clethra arborea	b	11.0
Clethra delavayii	a and b	9.0
Clethra fargesii	a and b	6.0
Colletia armata	a	8.0
Cordyline australis	b	13.0
Cornus alternifolia 'Argentea'	a	-
Cornus capitata	b	12.0
Cornus florida	a and b	-
Cornus kousa chinensis	a	-
Cornus nuttallii	a	-

Corokia x virgata	a and b	9.0
Corylopsis pauciflora	a	-
Crinodendron hookeranum	b	11.0
Cunninghamia lanceolata	a and b	8.0
Cupressus cashmiriana	b	12.0
Cupressus lusitanica	a and b	8.0
Cupressus macrocarpa & cvs	a	7.0
Cupressus sempervirens	a	6.0
Cytisus battandieri	a	7.0
Daboecia 'William Buchanan'	a	7.0
Danae racemosa	a and b	6.0
Daphniphyllum macropodum	a and b	7.0
Desfontainea spinosa	a and b	8.0
Deutzia hybrida cvs	a	5.0
Diospyros khaki	a and b	-
Dicksonia antarctica	b	13.0
Drimys winteri	b	11.0
Embothrium coccineum lanceolatum	a	8.0
Erica alpina 'Arborea'	a	5.0
Erica australis	b	9.0
Erica canaliculatus	b	14.0
Erica lusitanica	b	9.0
Erica veitchii 'Exeter'	b	10.0
Erythrina crista-galli	a and b	9.0
Escallonia 'Apple Blossom'	a	8.0
Escallonia 'Donard Radiance'	a	9.0
Escallonia 'Gwendolyn Anley'	a	8.0
Escallonia 'Iveyi'	b	11.0
Eucalyptus coccifera	a and b	10.0

Eucalyptus dalrympleana	b	9.0
Eucalyptus glaucescens	a and b	8.0
Eucalyptus globulus	b	14.0
Eucalyptus gunnii	a	8.0
Eucalyptus niphophila	a	8.0
Eucalyptus nitens	b	11.0
Eucalyptus parvifolia	a	7.0
Eucalyptus perriniana	b	11.0
Eucalyptus urnigera	a and b	8.0
Eucryphia cordifolia	b	11.0
Eucryphia 'Rostrevor'	a	6.0
Eucryphia nymansensis 'Nymansay'	a	6.0
Euonymus grandiflora	a	-
Euonymus japonica & cvs	a	6.0
Euphorbia venata (wulfenii)	a	8.0
Fabiana imbricata	a and b	10.0
Fabiana imb. 'Prostrata'	a	7.0
x Fatshedera lizei	a	7.0
Fatsia japonica	a	8.0
Feijoa sellowiana	b	11.0
Ficus carica	a	7.0
Fremontodendron californicum	b	14.0
Fuchsia 'Corallina'	a	5.0[1]
Fuchsia magellanica cvs	a	5.0[1]
Fuchsia 'Riccartonii'	a	5.0[1]
Fuchsia 'Mrs Popple'	a	5.0[1]
Garrya elliptica	a	7.0
Genista aetnensis	a	7.0
Genista lydia	a	6.0

Gleditsia triacanthos	a	-
Gleditsia 'Sunburst'	a and b	-
Griselinia littoralis	a	8.0
Griselina l. 'Variegata'	a and b	11.0
Halimiocistus ingwersii	a	10.0
Halimiocistus sahucii	a	9.0
Halimiocistus wintonensis	b	12.0
Halimium lasianthum	a	10.0
Halimium ocymoides	a	9.0
Hebe albicans	a	7.0
Hebe andersonii 'Variegata'	b	15.0
Hebe armstrongii	a	6.0
Hebe 'Carl Teschner'	a	8.0
Hebe cassinoides	a	8.0
Hebe cupressoides	a	6.0
Hebe 'Edinensis'	a	8.0
Hebe 'Great Orme'	b	12.0
Hebe hulkeana	b	11.0
Hebe 'Midsummer Beauty'	b	9.0
Hebe pinguifolia 'Pagei'	a	8.0
Hebe salicifolia	b	10.0
Hebe speciosa cvs	b	13.0
Hebe vernicosa	a	8.0
Hedera canariensis 'Gloire de Marengo'	a	9.0
Hibiscus syriacus	a	-
Hoheria glabrata	a and b	7.0
Hoheria lyalli	a and b	7.0
Hoheria sexstylosa	b	11.0
Hydrangea macrophylla cvs	a	6.0

Hydrangea quercifolia	a	5.0
Hydrangea serrata cvs	a	6.0
Hypericum 'Hidcote'	a	6.0
Hypericum indoratum'Elstead'	a	6.0
Hypericum x moserianum 'Tricolor'	a and b	6.0
Hypericum 'Rowallane'	b	11.0
Idesia polycarpa	a and b	6.0
Iilex verticilliata	a	-
Indigofera heterantha	a	7.0
Itea illicifolia	b	11.0
Jasminum officinale	a	7.0
Jasminum x stephanense	a	8.0
Kalmia latifolia	a and b	-
Laurus nobilis	a	9.0
Lavateria olbia 'Rosea'	a	10.0
Lapageria rosea	b	13.0
Leptospermum scoparium cvs	b	13.0
Leycesteria formosa	a	7.0
Ligustrum japonicum	a	7.0
Ligustrum lucidum	a	7.0
Ligustrum quihoui	a	6.0
Ligustrum sinense & cvs	a	-
Liquidamber styraciflua	a	-
Liriodendron tulipfera	a	-
Lithocarpus henryi	b	9.0
Lomatia ferruginea	b	12.0
Lomatia myricoides	a	9.0
Lonicera etrusca	a	6.0
Lonicera sempervirens	a	8.0

Lonicera splendida	a	7.0
Lupinus arboreus	a	8.0
Magnolia campbellii	a	7.0
Magnolia dawsoniana	a	8.0
Magnolia delavayi	b	11.0
Magnolia grandiflora	a	7.0
Magnolia hypoleuca	a	-
Magnolia sargentiana robusta	a	-
Magnolia soulangiana cvs	a	-
Magnolia sinensis	a	6.0
Magnolia x veitchii	a	-
Mahonia acanthifolia	b	10.0
Mahonia lomariifolia	a	8.0
Mahonia trifoliata glauca	a	-
Mandevilla suaveolens	b	12.0
Meliosma veitchorum	a and b	-
Muehlenbeckia complexa	a and b	8.0
Mutsia oligodon	a	8.0
Metasequoia glyptostroboides	a	-
Myrtus apiculata	b	14.0
Myrtus communis & cvs	b	14.0
Nothofagus betuloides	a	7.0
Nothofagus fusca	a	8.0
Nothofagus procera	a	5.0
Nothofagus solandri	a	9.0
Nyssa sinensis	a	6.0
Olearia avicenniifolia	a and b	11.0
Olearia x haastii	a	7.0

Olearia macrodonta	a and b	11.0
Olearia nummulariifolia	a	6.0
Olearia phlogopappa	b	12.0
Olearia semidentata	b	14.0
Olearia solandri	b	11.0
Olearia stellulata 'Splendens'	b	13.0
Olearia traversii	b	13.0
Olearia 'Zennorensis'	b	11.0
Osmanthus armatus	a	7.0
Osmanthus delavayii	a	7.0
Osmanthus x fortunei	a	9.0
Osmanthus yunnanensis	a	
Oxydendrum arboreum	a and b	-
Parthenocissus henryana	a	8.0
Passiflora caerulea	b	12.0
Paulownia fargesii	a	-
Paulownia tomentosa	a	-
Phellodendron japonicum	a	-
Philadelphus agrocalyx	a	-
Philadelphus microphyllus	a	5.0
Phlomis fruticosa	a	8.0
Phormium tenax & cvs	a	8.0
Photinia x fraseri 'Robusta'	a	9.0
Photinia glabra 'Rubens'	a	9.0
Photinia serrulata	a	9.0
Phygelius capensis	a	6.0
Pieris formosa forrestii 'Wakehurst'	a and b	8.0
Pieris 'Forest Flame'	a	7.0

Pileostegia viburnoides	a and b	7.0
Pinus ayacahuite	a	8.0
Pinus coulteri	a	5.0
Pinus montezumae	b	11.0
Pinus patula	b	11.0
Pinus pinea	a	5.0
Pinus radiata	a	7.0
Pittosporum dalli	a	9.0
Pittosporum eugenoides	a and b	14.0
Pittosporum e. 'Variegatum'	b	14.0
Pittosporum patulum	a and b	9.0
Pittosporum tenuifolium	a and b	12.0
Pittosporum t.'Silver Queen'	b	13.0
Pittosporum t. 'Purpureum'	b	13.0
Pittosporum tobira	b	13.0
Podocarpus macrophyllus	b	10.0
Podocarpus salignus	b	11.0
Poncirus trifoliata	a	5.0
Prunus lustitanica 'Azorica'	a	7.0
Prunus lustitanica 'Variegata'	a	7.0
Punica granatum	a and b	9.0
Quercus canariensis	a	-
Quercus coccinea 'Splendens'	a	-
Quercus ilex	a	5.0
Quercus imbricana	a	-
Quercus myrsinifolia	a	-
Quercus suber	b	7.0
Raphiolepis x delacourii	a and b	11.0
Rhamnus alaterna	a	8.0

Rhamnus alaterna 'Argenteovariegata'	a	8.0
Rhus potannii	a	-
Ribes laurifolium	a	6.0
Ribes speciosum	a and b	10.0
Robinia pseudoacacia	a	-
Robinia 'Frisia'	a and b	-
Robinia 'Hilleri'	a	-
Robina hispida	a	-
Romneya coulteri	a	5.0 [1]
Rosa brunonii 'La Mortola'	b	12.0
Rosa 'Mermaid'	a and b	10.0
Rosmarinus lavandulaceus	b	13.0
Rosmarinus officinalis	a	8.0
Ruscus hypoglossum	a	-
Salvia officinalis	a	7.0
Santolina chamaecyparissus	a	7.0
Santolina virens	a	7.0
Sarcococca ruscifolia	a	8.0
Sassafras albidum	a	-
Schizandra grandiflora rubriflora	a	-
Senecio elaegnifolius buchannii	a	10.0
Senecio reinoldii	b	12.0
Senecio 'Sunshine'	a	9.0
Solanum crispum	a and b	10.0
Solanum jasminoides 'Alba'	b	13.0
Sophora japonica	a	-
Sophora tetraptera	a and b	11.0
Spartium junceum	a	8.0

Stachyurus chinensis	b	-
Stachyurus praecox	a	-
Stranvaesia davidiana	a	8.0
Styrax japonica	a	5.0
Telopea truncata	b	10.0
Teucrium fruticans	b	13.0
Trachelospermum asiaticum	a and b	9.0
Trachelospermum jasminoides	b	10.0
Trachycarpus fortunei	a	7.0
Trochodendron aralioides	a	
Viburnum cinnamomifolium	a and b	7.0
Viburnum grandiflorum	a and b	6.0
Viburnum henryi	a	6.0
Viburnum macrocephalum	b	9.0
Viburnum tinus	a	8.0
Viburnum tinus 'Variegatum'	b	10.0
Vinca major 'Variegata'	a	8.0
Wisteria floribunda & cvs	a and b	-
Yucca gloriosa	a	6.0
Zelkova serrata	a	-

- = no data, included in questionnaire for responses other than winter hardiness

1 = as a herbaceous plant

7.3 Lowest Growing Season Solar Radiation and Summer WarmthZone in which a Plant can Perform Satisfactorily

Plantbase topics involved:

flower_sun
flower_sun-inter
flower_inter-shade
flower_shade
flower_sun-shade

growth_sun
growth_sun-inter
growth_inter-shade
growth_shade
growth_sun-shade

warmth_necessary

As discussed in 3.2 aspects of plants performance such as the initiation of floral parts and the level of phenotypic expression can often be traced back to the plants carbohydrate balance. In the field photosynthetic productivity is frequently limited by shortages of either, light, accumulated temperature or water.

This section considers the influence of light and temperature, on the performance of decorative plants in the landscape, and how Plantbase documents these relationships.

The influence of the growing season temperature and radiation regime upon plant performance can be considered as:

a) plant response to the overall insolation - temperature regime of an area in the absence of modifying factors, i.e. as described by the basic climatic classification of Climatebase. (see Table 6.15 and 6.21)

b) Plant response to a modified insolation - temperature regime as a result of interactions with relief, buildings or vegetation, e.g. localised shading.

For convenience both of the above can be further subdivided:

i Response of the vegetative phenotype

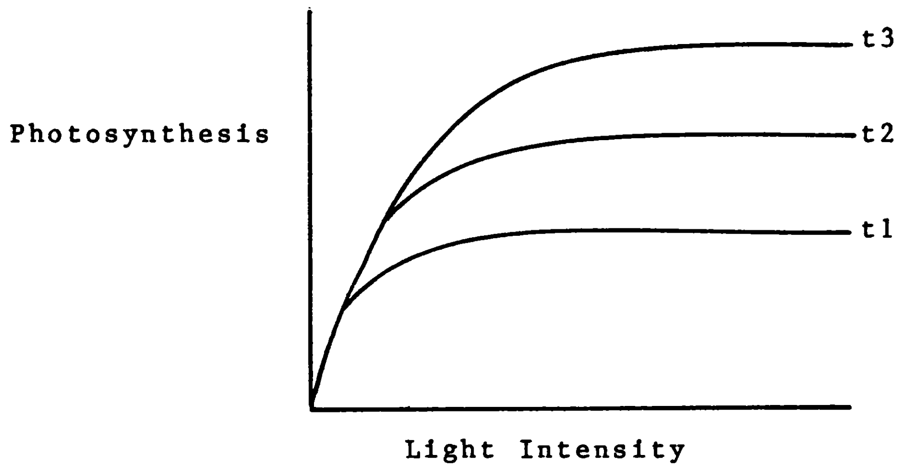
ii Response of the reproductive phenotype

7.3.1 Plant Response to the Overall Growing Season Insolation-Temperature Regime

The relative uniformity of insolation regimes across England and Wales has already been discussed. When however insolation differentials are examined in the context of the associated summer warmth regime, it is apparent that potential photosynthesis may vary considerably from area to area (Landsberg 1972-3).

Fig 7.2 Relationship Between Temperature, Solar Radiation and the Rate of Photosynthesis

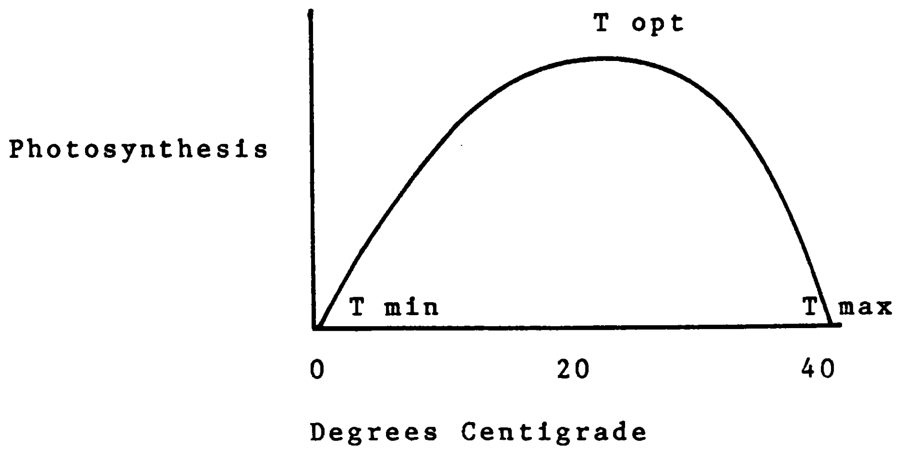
(Adapted from Sutcliffe 1977)



Minimum, maximum and optimum temperatures can be identified for the process of photosynthesis. These temperatures generally correlate with those prevailing in a species natural distribution and are known as cardinal temperatures.

Fig 7.3 Representative Cardinal Temperatures for Photosynthesis

(Adapted from Pisek, Larcher, Vegis & Napp Zin 1973)



This characteristic response curve, with 3 cardinal points arises because temperatures affects biochemical processes in two mutally antagonistic ways;

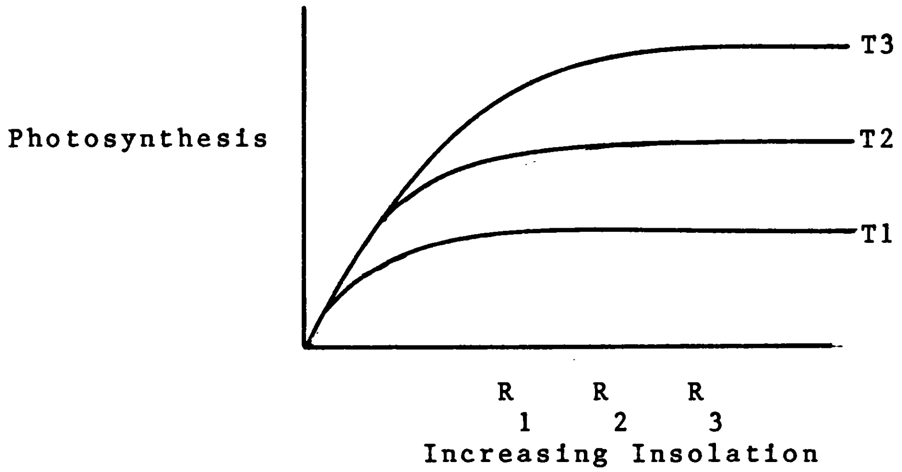
a) A rise in temperatures increases reaction rates and thereby photosynthesis
b) Temperatures beyond a defined value increase enzyme deactivation, decreasing photosynthesis

The optimum temperature for photosynthesis is ecotype rather than species determined and represents the balance point between these two processes. In a species natural distribution, even if light and temperature are not limiting actual photosynthetic productivity is likely to be well below what that species is capable of due to additional factors such as water stress.

Even though the relative absence of water stress in many parts of Britain may to some extent compensate for (in terms of fresh weight gain) low insolation and temperature regimes, many woody plants originating from continental regions or more southerly latitudes must experience difficulties accumulating sufficient photosynthates to fuel their developmental processes.

These taxa may therefore be incapable of performing as satisfactory landscape vegetation in the cooler parts of England and Wales, although they may still be considered as satisfactory garden plants as acceptable performance may be attainable if suitable microclimates can be provided, e.g shelter from wind and wall training. The importance of microclimate selection on plant performance is illustrated in Fig 7.4

Fig 7.4 <u>Diagramatic Representation of the Relationship Between Potential Photosynthesis, Insolation and Temperature for 3 Climatic Regions</u>



R_1 = Insolation in Northern England
R_2 = Insolation in Southern England
R_3 = Insolation in a Continental Climate

T_1 = Growing Season Warmth in Northern England
T_2 = Growing Season Warmth in Southern England
T_3 = Growing Season Warmth in a Continental Climate

In the landscape the individual specimens location is usually subservient to the overall design thus location in the most suitable microclimate is seldom possible.It is important therefore that plants which require these more precise locations should be identified on an information system aimed at the landscape professions.

Table 7.5 illustrates in terms of growing season warmth the potential suitability of areas of England for the cultivation of some familiar plants of the Korean

Peninsula. This data also demonstrates how the re-introduction of taxa into cultivation from upper altitudinal distributions could contribute to extending the potential use of such plants in landscape.

Table 7.5 Natural Distribution of some familiar Korean Plants as Defined by Kira s' Warmth Index (WI) : Comparisons with the Warmth Index of 2 Regions of England. (Adapted from Yim 1977 a,b)

Species	WI at species lower altitudinal limit	WI at species upper altitud -inal limit
Pinus pumila	78.5	6.9
Betula ermanii	81.7	15.8
Picea jezoensis	69.7	18.3
................................lowland Northumberland WI = 45.3 (Area 1s)		
Magnolia sieboldii	100.3	45.8
Cornus controversa	113.1	45.8
Callicarpa japonica	114.8	52.2
Styrax obassia	112.2	56.1
Picrasma quassioides	107.2	57.8
................................Surrey WI = 58.0 (Area 32)		
Camellia japonica	117.8	69.7
Phyllostachys bambusoides	111.5	81.0

Growing season warmth measured by Kiras' Warmth Index (Yim & Kira 1975)

WI = $\sum(t - 5)$ for months when $t > 5$ degrees centigrade. t = average monthly mean

a) Vegetative Plant Performance in Response to the Overall Insolation - Temperature Regime

Plantbase topic involved:

growth_sun

warmth_necessary

Taxa exhibiting unsatisfactory vegetative form or growth rates as a result of markedly sub-optimal temperature regimes comprise only a small percentage of potentially useful landscape plants.

Given that many landscape plants originate from warmer summer climes, the fact that most decorative plants are satisfactory attests to the great plasticity of the vegetative plant.

At the same time the performance of many plants judged to be satisfactory in Britain will be far below that which they can achieve in more suitable climates. Working with a range of familiar herbaceous pasture plants Blackman and Black (1959) came to the conclusion that; "for all species the assimilation rate of unshaded plants was limited by light even though in high summer the recorded light energy between 4,000 - 7,000 A averaged 1,900 - 2,200 foot candles."

Table 7.6 Calculated Light Levels for the Maximal Relative Growth Rate of Some Herbaceous Plants

Species	Natural Distribution	Optimal light level (daylight in UK = 1)
Helianthus annuus	Mexico	1.14
Medicago sativa	Mediterannean & W Asia	2.51
Trifolium hybridum	Europe (not U.K)	1.48
" pratense	U.K and Europe	1.00
" repens	U.K and Europe	0.85

Plants which do exhibit unsatisfactory form and limited vigour are generally those indigenous to regions experiencing continental climates, and include many familiar arborescent species such as Ailanthus altissima, Gleditsia triacanthos, Liquidamber styraciflua and Platanus x acerifolia all of which grow weakly not only in Northern England but also in cold exposed locations further south.

In addition to these indicator species a much wider range of plants exhibit a reduction in vigour and ultimate stature e.g Arbutus unedo and Cercis siliquastrum rarely assumes tree status in Northern England (Smith 1973).

Little attention has been paid to these responses in the decorative plant literature which is largely based upon observations made firstly in the areas most favoured in terms of insolation and temperature, and secondly, in the special environment of the garden where plant response may be masked by husbandry.

The few texts which record the responses of decorative plants in parts of Northern England (North 1967, Smith 1973) highlight the unreliable performance of what in the south are thoroughly reliable species.

A small number of decorative plants, only a few of which are of landscape potential, e.g Salix lanata, originate from very high latitudes and or altitudes the reverse appears to hold. These plants are easily cultivated in Northern England and Scotland, but prove difficult in Southern England.

It is possible that in the relatively warm growing season of Southern England such plants may be forced to operate too close to their compensation point to maintain a satisfactory carbohydrate balance and are consequently unreliable. (Daubenmire 1974, Moore 1976)

b) Reproductive Plant Performance in Response to the Overall Insolation - Temperature Regime

Plantbase topics involved:

flower_sun

warmth_necessary

"Reproductive" is used in this section to refer primarily to flower and fruit production and not necessarily the production of viable seeds. As for the sub-optimal overall insolation and temperature regimes, these are more readily mirrored in the reproductive as opposed the vegetative specimen. The plant must accumulate a given level of carbohydrate, if it is to be capable of initiating flower buds, developing fruits and finally producing viable seed. (Kramer & Kozlowski 1979).

The latter two processes are the first to be jettisoned by the plant in response to insufficient insolation and temperature. This is demonstrated even by indigenous species such as Tilia cordata (Piggott & Huntley 1978) and Nardus strictus (Pearsall 1965).

Some introduced species react even more dramatically and even fail to initiate flower buds in certain regions of England and Wales. This retardation of flowering commonly occurs at the following levels:

i It may be absolute, the plants carbohydrate balance being so unsatisfactory that it remains permanently vegetative or initiates only a small number of flower buds.

ii Temporary, the characteristic length of the juvenile, non-reproductive phase being extended due to the slow accumulation of dry matter. When the plant does eventually become reproductive, performance may be either satisfactory or permanently suppressed in terms of inflorescence numbers.

Amongst the many familiar decorative plants which dramatically demonstrate this type of response are the following :

Cornus kousa chinensis

Cercis siliquastrum

Hibiscus syriacus

Magnolia grandiflora

Wisteria sinensis

In order to quantify plant response to the overall temperature and insolation climate, the woody subjects listed in Plantbase were scanned for those which were likely to produce unsatisfactory vegetative and or reproductive performances in some parts of England and Wales. The aim was to allocate the rating which represents the minimum solar radiation and summer warmth zone, (as defined by Climatebase) in which each genotype could produce a satisfactory vegetative or floral phenotype.

Information on the performance of identified taxa was obtained from the authors surveys of plant collections throughout England and Wales. As the prevailing solar radiation and summer warmth regime could be estimated from Climatebase, each collection acted as a reference point against which comparisons of performance could be made.

The collections surveyed and their insolation - temperature climates are documented in Table 7.2 . Taxa not identified are assumed to be capable of producing a satisfactory vegetative and floral phenotype in solar radiation and summer warmth zones of 2 or greater, and are listed as such in Plantbase.

The data received from these surveys was analysed and ratings produced for each taxa. These are documented in Table 7.7, and reflect not only the authors surveys but a thorough review of the most useful decorative literature. (Stern 1960, North 1967, Evans 1972a,b, Smith 1973, Bean 1973-1980, Lloyd 1973, Verney 1976, Lemmon 1978)

Table 7.7 Survey Derived Minimum Growing Season Solar Radiation and Summer Warmth Zones in which Satisfactory Performance is Possible

Plant Name	Vegetative Growth		Reproductive Growth	
	Solar Radiation Zone	Summer Warmth Zone	Solar Radiation Zone	Summer Warmth Zone
Abutilon megapotamicum	4.0	6.0	4.0	6.0
Acacia baileyana	2.0	3.0	2.0	4.0
Acacia dealbata	2.0	3.0	2.0	4.0
Acacia pravissima	2.0	3.0	2.0	4.0
Acacia riceana	2.0	3.0	2.0	4.0
Akebia trifoliata	3.0	5.0	3.0	5.0
Albizia julibrissin 'Rosea'	4.0	6.0	4.0	6.0
Arbutus x andrachnoides	2.0	3.0	2.0	4.0
Arbutus menziesii	2.0	3.0	2.0	4.0
Arbutus unedo	2.0	3.0	2.0	4.0
Azara microphylla	2.0	3.0	3.0	4.0
Azara microphylla 'Variegata'	3.0	4.0	3.0	4.0
Berberis valdiviana	3.0	4.0	3.0	4.0
Billardia longiflora	2.0	3.0	2.0	3.0
Buddleia colvilei 'Kewensis'	3.0	4.0	3.0	5.0
Caesalpinia japonica	3.0	4.0	3.0	4.0
Camellia reticulata	3.0	4.0	3.0	4.0
Campsis 'Mme. Galen'	3.0	5.0	4.0	6.0 +

Catalpa bignonoides	3.0	5.0	3.0	5.0	
Catalpa fargesii	3.0	5.0	3.0	5.0	
Catalpa speciosus	3.0	5.0	3.0	5.0	
Ceratostigma willmottianum	2.0	3.0	2.0	3.0	
Cercis siliquastrum	3.0	4.0	3.0	5.0	
Chimonanthus praecox	4.0	6.0	4.0	6.0	
Chionanthus retusus	3.0	5.0	4.0	6.0	
Chionanthus virginicus	3.0	5.0	4.0	6.0	
Clerodendron trichotomum	3.0	5.0	4.0	6.0	
Clethra delavayii	3.0	5.0	3.0	5.0	
Clethra fargesii	3.0	5.0	3.0	5.0	
Colletia armata	3.0	5.0	3.0	5.0	
Cornus alternifolia 'Argentea'	3.0	4.0	3.0	4.0	
Cornus florida	2.0	3.0	4.0	5.0	
Cornus kousa chinensis	2.0	3.0	4.0	5.0	
Corylopsis pauciflora	3.0	4.0	3.0	4.0	
Cunninghamia lanceolata	3.0	4.0	-	-	
Cupressus cashmiriana	3.0	5.0	-	-	
Danae racemosa	3.0	5.0	-	-	
Diospyros khaki	3.0	5.0	3.0	5.0	
Erythrina crista-galli	4.0	6.0	4.0	6.0	+
Eucryphia cordifolia	2.0	4.0	2.0	4.0	
Eucryphia 'Rostrevor'	2.0	3.0	2.0	3.0	
Eucryphia nymansensis 'Nymansay'	2.0	3.0	2.0	3.0	
Fatsia japonica	2.0	3.0	-	-	
Feijoa sellowiana	3.0	5.0	3.0	5.0	
Ficus carica	3.0	5.0	3.0	5.0	
Fremontodendron californicum	2.0	3.0	2.0	3.0	

Garrya elliptica	2.0	3.0	2.0	3.0
Genista aetnensis	2.0	3.0	2.0	3.0
Gleditsia triancanthos	3.0	5.0	3.0	5.0
Gleditsia 'Sunburst'	3.0	5.0	-	-
Hibiscus syriacus	3.0	5.0	4.0	6.0
Hoheria glabrata	2.0	3.0	2.0	3.0
Hoheria lyalli	2.0	3.0	2.0	3.0
Hoheria sexstylosa	2.0	3.0	2.0	3.0
Hydrangea quercifolia	3.0	5.0	4.0	6.0
Idesia polycarpa	3.0	5.0	3.0	5.0
Ilex verticilliata	3.0	5.0	3.0	5.0
Indigofera heterantha	3.0	5.0	3.0	5.0
Jasminum officinale	2.0	3.0	2.0	3.0
Kalmia latifolia	3.0	5.0	3.0	5.0
Koelreuteria paniculata	4.0	6.0	4.0	6.0
Lapageria rosea	2.0	4.0	2.0	4.0
Ligustrum japonicum	3.0	5.0	3.0	5.0
Ligustrum lucidum	2.0	5.0	3.0	5.0
Ligustrum quihoui	3.0	5.0	4.0	6.0
Ligustrum sinense & cvs	3.0	5.0	3.0	5.0
Liquidamber styraciflua	3.0	5.0	-	-
Liriodendron tulipfera	3.0	5.0	-	-
Lomatia myricoides	3.0	5.0	3.0	5.0
Lonicera etrusca	2.0	3.0	2.0	3.0
Lonicera sempervirens	2.0	3.0	3.0	4.0
Lonicera splendida	2.0	3.0	2.0	3.0
Magnolia campbellii	2.0	3.0	3.0	4.0
Magnolia delavayi	2.0	4.0	3.0	4.0
Magnolia grandiflora	4.0	6.0	4.0	6.0
Magnolia hypoleuca	2.0	4.0	3.0	5.0

Magnolia sargentiana robusta	2.0	4.0	2.0	4.0	
Magnolia soulangiana cvs	2.0	4.0	2.0	4.0	
Magnolia sinensis	3.0	5.0	3.0	5.0	
Meliosma veitchorum	3.0	5.0	-	-	
Mutsia oligodon	3.0	5.0	3.0	5.0	
Metasequoia glyptostroboides	3.0	5.0	-	-	
Myrtus apiculata	3.0	5.0	3.0	5.0	
Myrtus communis & cvs	3.0	5.0	3.0	5.0	
Nothofagus betuloides	3.0	5.0	-	-	
Nothofagus fusca	3.0	5.0	-	-	
Nothofagus procera	3.0	5.0	-	-	
Nothofagus solandri	3.0	5.0	-	-	
Nyssa sinensis	3.0	5.0	-	-	
Osmanthus armatus	2.0	4.0	2.0	4.0	
Osmanthus delavayii	3.0	5.0	3.0	5.0	
Osmanthus yunnanensis	2.0	3.0	-	-	
Oxydendrum arboreum	4.0	5.0	4.0	5.0	
Passiflora caerulea	3.0	5.0	3.0	5.0	
Paulownia fargesii	4.0	6.0	4.0	6.0	+
Paulownia tomentosa	4.0	6.0	4.0	6.0	
Philadelphus microphyllus	3.0	5.0	3.0	5.0	
Photinia serrulata	2.0	4.0	3.0	5.0	
Pieris formosa forrestii 'Wakehurst'	2.0	4.0	2.0	4.0	
Pieris 'Forest Flame'	2.0	4.0	2.0	4.0	
Pileostegia viburnoides	3.0	4.0	3.0	4.0	
Pinus ayachuite	2.0	4.0	-	-	
Pinus coulteri	2.0	4.0	-	-	
Pinus montezumae	2.0	4.0	-	-	

Pinus patula	2.0	4.0	-	-
Pinus pinea	2.0	4.0	-	-
Pinus radiata	2.0	3.0	-	-
Pittosporum tobira	2.0	4.0	2.0	4.0
Podocarpus macrophyllus	3.0	5.0	-	-
Podocarpus salignus	2.0	4.0	-	-
Poncirus trifoliata	4.0	6.0	4.0	6.0
Punica granatum	4.0	6.0	4.0	6.0
Quercus canariensis	2.0	4.0	-	-
Quercus coccinea 'Splendens'	3.0	5.0	-	-
Quercus ilex	2.0	3.0	-	-
Raphiolepis x delacourii	3.0	5.0	3.0	5.0
Rhamnus alaterna 'Argenteovariegatus'	2.0	3.0	-	-
Rhus potannii	2.0	3.0	-	-
Ribes speciosum	3.0	5.0	3.0	5.0
Robinia pseudoacacia	2.0	3.0	-	-
Robinia 'Frisia'	3.0	5.0	-	-
Robina 'Hilleri'	3.0	5.0	3.0	5.0
Robina hispida	3.0	5.0	3.0	5.0
Romneya coulteri	2.0	4.0	2.0	4.0
Rosa brunonii 'La Mortola'	4.0	6.0	4.0	6.0
Rosa 'Mermaid'	3.0	5.0	3.0	5.0
Sassafras albidum	4.0	6.0	-	-
Schizandra grandiflora rubriflora	2.0	4.0	2.0	4.0
Solanum crispum	2.0	4.0	2.0	4.0
Solanum jasminoides	2.0	3.0	2.0	3.0
Sophora japonica	2.0	4.0	4.0	6.0
Styrax japonica	2.0	4.0	2.0	4.0

Telopea truncata	3.0	5.0	3.0	5.0
Teucrium fruticans	2.0	3.0	2.0	3.0
Trachelospermum asiaticum	3.0	5.0	3.0	5.0
Trachelospermum jasminoides	3.0	5.0	3.0	5.0
Trachycarpus fortunei	2.0	4.0	-	-
Trochodendron aralioides	2.0	3.0	2.0	3.0
Viburnum cinnamomifolium	3.0	5.0	3.0	5.0
Viburnum grandiflorum	2.0	4.0	2.0	4.0
Viburnum henryi	3.0	4.0	3.0	4.0
Wisteria floribunda	3.0	5.0	3.0	6.0
Yucca gloriosa	2.0	2.0	3.0	4.0
Zelkova serrata	2.0	4.0	-	-

7.3.2 Plant Response to Modified Insolation Regimes

In practice the interaction of landform, buildings and vegetation with sunlight often results in plants having to contend with greatly modified insolation regimes.

Localised shade as generated by these interactions has a marked effect upon the phenotype of species which do not generally show any discernable response to regional variations in England and Wales insolation - temperature climate.

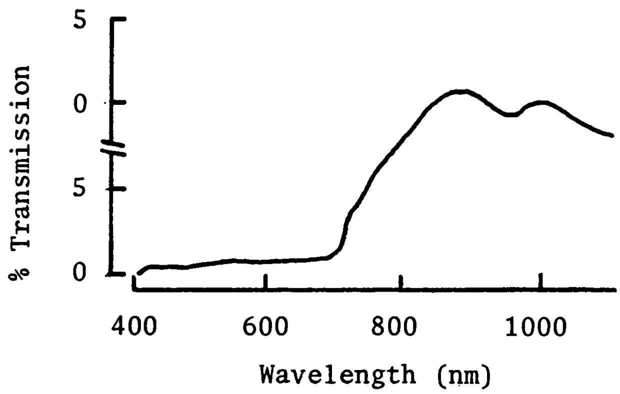
For the purposes of Plantbase the reduction in light energy due to localised shading is assumed to be accompanied by an equivalent reduction in leaf temperatures i.e the photosynthesis-respiration balance is assumed to remain constant.

Within Plantbase, a plants performance (vegetative and reproductive) is assessed and recorded in response to the following categories of localised shading:

full sun to light shade
light shade to shade
full shade
full sun to full shade (i.e complete tolerance)

Quantifying plant response to levels of shading is complicated by the need to distinguish between "neutral shade" as generated by buildings and landform and shade generated by light transmission through an overhead canopy of vegetation. The latter is characterised by its enhanced far red component which initiates morphogenetic changes in susceptible understory plants. These changes are often considered to be aesthetically undesirable.

Fig 7.5 Transmission Spectrum of a Woodland Canopy of *Quercus robur* (Adapted from Fitter & Hay 1981)



Quantification difficulties arise when comparing the photosynthetic potential of plants grown in these 2 types of shade. What might be termed "full shade" resulting from buildings is likely to represent a much higher energy regime due to the considerable diffuse insolation component, than full shade under a tree where the latter is likely to be largely absent. These difficulties remain unresolved within Plantbase.

Even when the two types of shade are of the same intensity in terms of radiant flux density, (i.e total energy) as a result of its altered spectral composition vegetation generated shade inhibits dry matter accumulation in heliophytes more than neutral shade does. (Fitter & Ashmore 1974).

Skiophytes do not exhibit this differential response. Characteristic heliophytic and skiophytic genera are shown in Table 7.8. The differential performance of decorative plants in neutral and vegetation generated shade has long been recorded in the horticultural literature for a wide range of species e.g the prostrate Cotoneasters, although the analysis of cause has generally been incorrect (Thomas 1970)

On Plantbase the user is informed via Additional Features of shade tolerant species which will also maintain an acceptable phenotype in vegetation generated shade.

Table 7.8 Characteristic Heliophytic and Skiophytic Arborescent Genera (From Daubmenmire 1974)

Heliophytes	Skiophytes
Betula	Abies
Salix	Acer
Populus	Fagus
Liriodendron	Quercus
Pinus	Tilia
Larix	Picea
Juniperus	Taxus
	Tsuga

NB Skiophytes typically possess greatest shade tolerance during their youth

a) Vegetative Performance in Response to Localised Shading

Plantbase topics involved:

growth_sun-inter
growth_inter-shade
growth_shade
growth_sun-shade

The possible range of the performance responses of heliophytes and skiophytes in the landscape are illustrated in Table 7.9.

During their youth many climax components actually grow better in terms of fresh and dry weight gain per unit of time, at 50% as opposed to 100% of daylight as has been demonstrated by the performance of *Fagus grandifolia* in Canada (Logan 1973). At this stage in their development such plants frequently suffer reversible damage due to chloroplast malformation when growth in full light. (Fitter & Hay 1981).

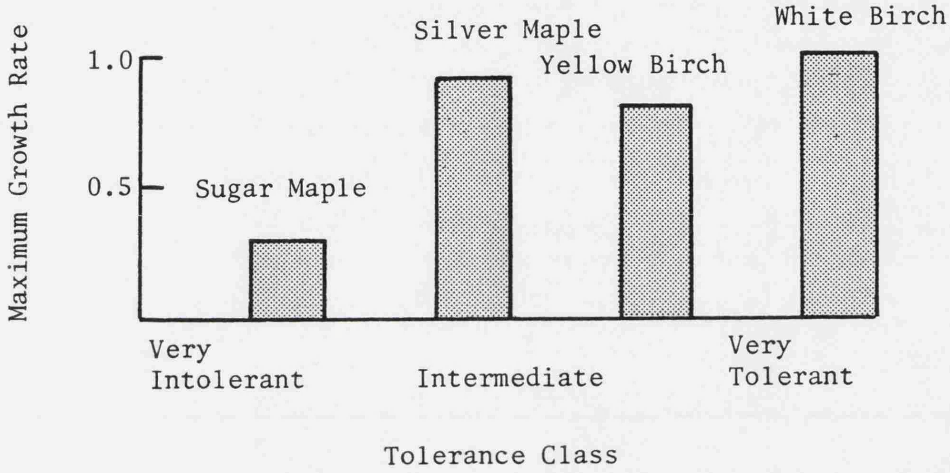
Tolerance of shade during the juvenile phase confers many advantages to arborescent woodland components, but is absent from most obligative heliophytes such as Pinus species. (Fairburn & Neustein 1970)

Table 7.9 Vegetative Performance of Woody Landscape Plants in Response to Localised Shading

Shading Gradient	Response of Obligative Heliophytes	Facultative Heliophytes	Facultative Skiophytes	Response of Obligative Skiophytes
Full sun	Satisfactory phenotype			Unsatisfactory phenotype foliage chlorotic and unattractive due to chlorophyll breakdown browned at margins by end of season. Plant stressed and stunted
Light shade	Morphological change, canopy becomes more open decline in number of branches. (Logan 1965) May still be judged to be satisfactory			Progressive improvement in phentoype. Leaf damage reduced, vigour increases

Semi shade	Morphological change continues. Increase in leaf size, reduction in extension growth, although increase in height may continue. Leaf and branch abscision continues.Plants appear thin with low leaf density.Dry weight gain decreasing.	
Full shade	Continued decline leading to foliage loss and death as carbohydrate deficit mounts	Satisfactory phenotype large and luxuriant foliage. Etiolation responses absent. Growth may be slow

Fig 7.6 Shade Tolerance of 4 Trees Related to Growth Potential (Adapted from Logan 1965, 1973) of White Birch



The capacity of skiophytes to tolerate low light levels, i.e maintain a positive carbon balance is normally achieved via the following strategies:

i Reduction in respiration rate (thereby growth) to lower the compensation point (see Fig 7.6)

ii Increased leaf area to increase potential light interception.

iii Increased rate of photosynthesis per unit area of leaf.

The compensation points of heliophytes are characteristically much higher at approximately 30% of full sunlight, than those of skiophytes which can be as low as 2.0% of full sunshine (Daubenmire 1974).

The characteristic form of the facultative heliophyte exposed to limited shading may be desirable, especially where a more open canopy is desired. Increasing the depth and duration of shade eventually results in unacceptable phenotypes, especially where vegetation generated shade is involved.

A large number of popular landscape shrubs are obligative heliophytes, for example the genus Rosa, and as such are unsuitable even as vegetative plants in shade.

b) Reproductive Performance in Response to Localised Shading

Plantbase topics involved:

flower_sun-inter
flower_inter-shade
flower_shade
flower_sun-shade

As previously mentioned, for most obligative and or facultative heliophytes the unfavourable carbohydrate balance associated with localised shade results in a rapid reduction in flower bud initiation, fruit set and fruit development. The results of shade on flower production in apple, a typical temperate heliophyte is shown in Table 7.10

Table 7.10 <u>The Effect of Artificial Shading on Fruit Bud Numbers in the Following Year</u> (for Apple)

(Data from Jackson & Palmer 1977 b)

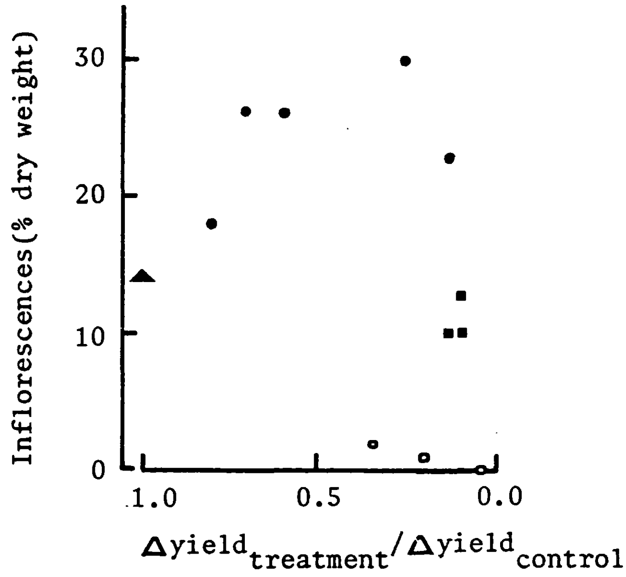
Light intensity as a % of full sunlight	Number of flower buds
100	159
37	96
25	69
11	26

The reproductive processes of woody plants are much more sensitive to reduced light levels than are vegetative processes. (Jackson & Palmer 1977a,b).

There are relatively few temperate skiophytes other than those with summer dormancy strategies, which can flower satisfactorily in dense shade (Grimes 1981). Indeed skiophytes may flower most profusely at light intensities that are sufficiently high to be detrimental to the vegetative plant, e.g in full sun <u>Vinca minor</u> flowers profusely although under these conditions its foliage is often chlorotic. The importance of shading over other environmental stresses in determining floral performance in heliophytes is illustrated in Fig 7.7

Fig 7.7 Comparison of Effect of Various Stresses on Dry Matter Allocation to Flowering in Poa annua

(Adapted from Grime 1981)



∘ = shading (neutral)

▪ = mineral nutrient stress

• = water stress

▲ = control

The reproductive performance of plants that are neither obligative heliophytes or skiophytes in localised shade may differ dramatically depending on the prevailing insolation - temperature regime. For example, in Southern England Camellia japonica will flower satisfactorily in heavy shade, where as in Northern England, full sun is necessary to induce the same level of performance.

These subtle interactions probably occur with many other plants, but have not been investigated. The characteristic reproductive responses of heliophytes and skiophytes to localised shading are shown in Table 7.11.

Vegetative and reproductive performance in response to shading has been quantified for taxa within Plantbase by allocating a rating which represents the minimum growing season solar radiation zone in which a plant can produce a satisfactory phenotype in a defined shading range. These shading ranges are as follows:

full sun to light shade	sun-inter
light shade to shade	inter-shade
full shade	shade
complete range, from full sun to full shade	sun-shade

Few plants can perform equally satisfactorily across a wide range of shading levels and correspondingly for any taxon on Plantbase, positive ratings cease at shading levels beyond which that genotype can no longer perform satisfactorily.

For example, with a heliophyte such Rosa rugosa, vegetative and reproductive performance would be documented on Plantbase as follows:

growth_sun-inter	2	flower_sun-shade	2
growth_inter-shade	-1	flower_inter-sun	-1
growth_shade	-1	flower_shade	-1
growth_sun-shade	-1	flower_sun-shade	-1

i.e the vegetative plant is of satisfactory appearance in full sun to light shade in growing season solar

Table 7.11 Reproductive Performance of Woody Landscape Plants in Response to Localised Shading

Shading Gradient	Response of Obligative Heliophytes	Facultative Heliophytes	Facultative Skiophytes	Response of Obligative Skiophytes
Full sun	Satisfactory phenotype			Generally satisfactory although vegetative plant may be severely stressed
Light shade	Decline in number of flowers intiated and fruit set. Decline greatest in vegetation generated shade			
Semi shade				Progressively less satisfactory floral performance
Full shade	Unsatisfactory phenotype no floral initiation			

radiation zone 2 or any sunnier zone.

Although it may cause some confusion -1 is used within Plantabase to indicate an absence of data within a defined data field.

For a skiophyte such as Mahonia japonica vegetative and reproductive performances would be recorded as:

growth_sun-inter	-1	flower_sun-inter	2
growth_inter-shade	2	flower_shade	2
growth_shade	2	flower_shade	2
growth_sun-shade	-1	flower_sun-shade	2

The ratings that have actually been incorporated into Plantbase are based on information derived from a general review of the decorative plant literature supplemented by specialist sources such as; (Fish 1964, Brown 1980, Paterson 1981),and the authors observations of plant performance in the collections documented in Table 7.2.

For many genotypes "cut off" points beyond which performance is unsatisfactory are not known with any certainty and in these cases the ratings must be seen as informed estimates. The allocation of ratings is further complicated by interaction with the overall areal insolation temperature regime and the lack of data has made it impossible to document suspected "sliding scale" responses as in the case of Camellia japonica.

7.4 Maximum Soil Moisture Stress Zone in Which an Established Plant Can Perform Satisfactorily

Plantbase topic involved:

soil_moisture_deficit

As discussed in 6.6 the soil moisture deficit classification of Climatebase can not take account of the different AWC of various planting substrates. The soil moisture deficit concept as discussed in this thesis only allows comparison of available soil moisture in a generalised soil as a result of the varying precipitation- evaporation balance of different areas. Actual amounts of water available within any zone will vary depending upon aspect and substrate characteristics (holding capacity and drainage).

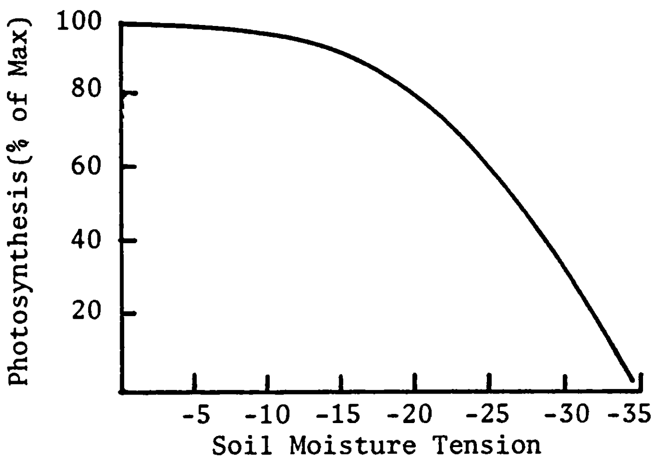
The plants tolerance of the range of soil moisture regimes from dry to permanently waterlogged is considered in 7.5 .

7.4.1 Effects of Soil Moisture Deficits on Plants and Derivation of Values

Soil moisture deficits affect the plant through the development of internal moisture deficits. In many species the development of internal water deficits are associated with the following events:

a) Stomatal closure occurs, reducing transpiration loss and therefore largely halting the development of further internal water deficits. As the stomates are the main routes for gaseous exchange, CO_2 ingress is reduced and photosynthesis is brought to a halt.

Fig 7.8 Effect of Internal Water Deficits on Photosynthesis of *Pseudotsuga menziesii* (Adapted from Kramer & Kozlowski 1979)



These immediate responses may also be accompanied by the following: (Kozlowski 1979)

b) Decrease in cell enlargement due to increased turgor pressure.

c) Inhibition of cell division.

d) Decrease in respiration and the translocation of carbohydrates and growth regulators.

e) Accumulation of abscisic acid, ultimately leading to the abscission of older leaves or branches.

f) Enzyme and therefore reduced metabolic activity.

In landscape plantings these physiological changes are manifested as:

a) Reduced size of new leaves, and ultimately the surface area of the leaf canopy. Where the stress is experienced over several seasons in many plants branch density is reduced, resulting in more a open canopy.

b) Reduced growth rates. Characteristically aerial growth declines more than root growth thereby increasing the survival capacity of plant. (Larcher 1975)

The physiological strategies plants have developed to avoid damage from internal water deficits are many and varied even amongst species facing similar stresses.

A plants innate capacity to cope with these stresses generally reflects the conditions prevailing in that species natural habitat. In cultivation the plant may be faced with either more or less severe soil moisture deficits than in the wild. In Britain once a specimen is established the latter applies to the majority of species.

In general plants originating from locations that experience relatively limited moisture stress close their stomates rapidly in response to a small increase in their internal moisture tension occasioned by developing soil moisture deficits. Such species may avoid dessication injury to their protoplasm but because of the limitations this strategy imposes on photosynthesis, may be characterised by unsatisfactory growth rates.

Some species adapted to dry environments also respond in this way whilst others maintain open stomates even as soil moisture tension deficits increase and internal moisture content decreases. (Helmuth 1969, Ladiges 1974)

Genotypes exhibiting this latter response avoid a dramatic decline in photosynthetic output and do not experience at least initially, such a marked decline in growth rate in response to increasing soil moisture tension. Most of the species which have adopted this strategy possess mechanisms by which their protoplasm can survive extreme internal water tensions as in the cases of *Pinus sylvestris*, and *Picea abies* (Larcher 1975).

The species adopting this strategy which are not innately tolerant of high internal water deficits are subject to occasional damage when faced with unsuitable conditions as in the case of some Fraxinus species, resulting in premature leaf senescence(Larcher 1975). All these responses are greatly influenced by additional factors such as relative humidity and wind velocity.

On the basis of vegetative performance in response to the range of soil moisture stress experienced within England and Wales, decorative woody plants can be considered as belonging to one of two groups:

a) Mesophytes whose vegetative performance is generally satisfactory in all areas, even those typically experiencing the most severe moisture deficits.

b) Mesophytes whose vegetative performance is generally unsatisfactory in the areas experiencing the highest soil moisture stress.

Many members of the first group originate from parts of world which experience a more arid climate than that of Britain. As such, given competent horticultural management, their ultimate development is more likely to be determined by factors other than moisture stress.

The majority of the woody plants of potential value to landscape belong to this group. When factors such as growing season warmth and insolation are not limiting, vegetative growth will be best in areas of England and Wales experiencing the smallest soil moisture deficits. Within Plantbase no attempt has been made to distinguish between levels of vegetative performance above that which is considered to be the minimum acceptable.

In the landscape, husbandry can be employed to minimise the impact of location upon performance and achieve the rapid initial rates of growth desired. The maintenance of high growth rates beyond the establishment period is not always necessary nor in some cases even desirable in landscape plantings.

The category of moisture sensitive decorative plants is largely composed of species originating from oceanic or mountainous regions of world where precipitation is both frequent and high, for example Chile, North Western America, Japan, New Zealand, and parts of the Himalayan regions. Typical temperate zone high rainfall genera are: Pieris, Crinodendron, Desfontainea, Rhododendron, Abies, Berberidopsis, Embothrium, Lomatia, Podocarpus, Nothofagus, and some of the Picea.

Members of these and other high rainfall genera are frequently subject to marked moisture stress in the regions of England and Wales which experience above average soil moisture deficits.

This stress may occasionally express itself as premature wilting and foliage abscission but more commonly it is manifested as slow growth and atypical form. Consequently many of these plants are only satisfactory landscape subjects when grown in the wetter parts of the British Isles typically the Western counties, Wales, and parts of Northern England and Scotland.

In the decorative plant literature, for example Bean (1973-1980), great emphasis is placed on the importance of high relative humidity to these plants. At low wind velocities, high relative humidities reduce the steepness of the water potential gradient between leaf and atmosphere thereby markedly reducing transpiration flow and minimising the occurrence of internal water deficits (Kramer & Kozlowski 1979). At high wind velocities the beneficial effects of humidity are much reduced. The influence of wind on growth is discussed in 7.6.

Although the parameter of soil moisture deficit is not a reliable indicator of relative humidity, it is still considered an acceptable means by which to define the tolerance of this group of plants, especially as many such species appear to perform satisfactorily in collections in Northern England, and Southern Scotland which experience relatively low humidity (Bilham 1938) providing soil moisture deficits are low. (Cooke 1967a,b, Verney 1976, Lady Howick of Glendale 1981)

Within Plantbase response to soil moisture deficits is assessed as the maximum soil moisture stress zone in which a plant can maintain a satisfactory form in the absence of regular irrigation. Factors such as soil type, localised rain shadows and weed competition all influence the actual soil moisture status at a given planting site, and it is inevitable that the user of Plantbase must be left to take this into account.

The species that are capable of sustaining acceptable vegetative performance in the driest areas of England have been identified by reference to the decorative plant literature.

On Plantbase these taxa have been ascribed a soil moisture stress rating of 5.0 indicating that they will perform satisfactorily in these and all less dry "moisture stress" zones.

For the remaining taxa it was necessary to identify the driest zone in which they could sustain a satisfactory performance.

The ratings for a plants response to soil moisture stress are based upon the authors surveys supported by a thorough review of the literature. (Forestry Comm. 1957, Chatto 1978, Bean 1973-1980,)

Table 7.12 summarises the zone ratings awarded to representatives of this latter group.

Table 7.12 <u>Survey Derived Maximum Soil Moisture Stress Zones in which Satisfactory Performance is Possible</u>

	Soil moisture Stress Zone:
Berberidopsis corallina	3.0
Billardia longiflora	3.0
Cercidiphyllum japonicum	4.0
Clethra arborea	4.0
Clethra delavayii	4.0
Clethra fargesii	4.0
Cornus nuttallii	4.0
Crinodendron hookeranum	3.0
Cunninghamia lanceolata	3.0
Desfontainea spinosa	3.0
Dicksonia antarctica	3.0
Drimys winteri	4.0
Embothrium coccineum lanceolatum	4.0
Eucryphia cordifolia	3.0
Eucryphia 'Rostrevor'	4.0
Eucryphia x nymansensis 'Nymansay'	4.0
Hoheria glabrata	4.0
Hoheria lyalli	4.0
Hoheria sexstylosa	4.0
Kalmia latifolia	4.0
Lapageria rosea	3.0
Lomatia ferruginea	3.0
Lomatia myricoides	3.0
Myrtus apiculata	4.0

Nothofagus betuloides	4.0
Nothofagus fusca	4.0
Nothofagus procera	4.0
Nothofagus solandri	3.0
Pieris formosa forrestii 'Wakehurst'	3.0
Pieris 'Forest Flame'	4.0
Podocarpus salignus	4.0
Sophora tetraptera	4.0
Telopea truncata	3.0

7.5 Plant Tolerance of Substrate Moisture Regimes

Plantbase topics involved:

water

The soil moisture deficit concept discussed in 7.4 assumes that the soil is at, or just below field capacity, i.e in terms of the potential soil moisture status it represents a median range. In practice many amenity substrates may experience conditions outside this range, being either waterlogged and anaerobic or extremely dry. The purpose of this topic is to assess the plants tolerance of the possible set of substrate moisture regimes that result from the interactions of the substrates physical nature, precipitation, evaporation and aspect. Excessively dry substrates are normally characterised by a pore volume in excess of 50% whilst substrates prone to anaerobosis are frequently associated with a smaller pore volumes, dominated by pores of less than 0.002mm diameter (Flegman & George 1975). Very few mesophytes,including the moisture demanding species identified in 7.4 can tolerate soils which waterlog. Field capacity represents a balance point between aerobic and anerobic conditions which is biologically satisfactory for the growth of most mesophytes.

For such plants the anaerobosis associated with waterlogging during periods of active growth represents a serious stress which may eventually result in the death of the root system of the plant. (Ruark, Mader, Tattar 1982). In the absence of sufficient oxygen in the root zone, (for many mesophytes greater than or equal to 5.0% of total soil volume), the plant is subjected to a potentially lethal combination of increasing external concentrations of ferrous and manganese ions and increasing internal concentration of ethylene, or even metabolites such as cyanides (Perry 1982).

Waterlogging during the dormant season when metabolic activity is low, appears as might be expected, to be much less damaging to most woody plants. (Ruark, Mader & Tattar 1983)

Plants which can tolerate waterlogged conditions during the growing season generally do so by supplying the roots with oxygen from the leaves, thereby sustaining satisfactory root respiration (Webster 1962). Such plants are also tolerant of high external ion concentrations.

The following range of substrate moisture regimes have been established as a scale against which to assess requirements.

Free water (submerged or floating hydrophytes only)
Free water-substrate interfaces
Wet to average (partially anerobic)
Average to dry
Dry through to wet

The soil moisture regime within which a genotype is adjudged to be capable of maintaining a satisfactory phenotype is recorded on Plantbase. The information upon which these assessments have been based has been derived from both field observations (see Table 7.2) and literature surveys. (Gill 1970, Bean 1973-1980, Hillier 1974, Kozlowski & Davis 1975, Humphries & Bradshaw 1977, Chatto 1978, Beardsall 1981)

7.6 Plant Response to Wind

Plantbase topic involved :

tol_expos

Britain is a very windy island, with the highest and most constant velocities experienced on the coasts and in upland regions (Manley 1975). For many decorative species, wind, due to its physiological and physical effects is a serious limitation to successful growth. The object of this topic is to indicate to the user of Plantbase, in terms of relative intensities, the growing season exposure beyond which satisfactory vegetative performance is unlikely to be attainable.

7.6.1 Physical and Physiological Effects of Wind on Plants

The most obvious effect of high wind velocities on plants is that of mechanical defoliation, to which large leaved species are particularly prone. Taxa which are unusually subject to wind breakage, wind-throw or defoliation in response to exposure are identified in User Limitations.

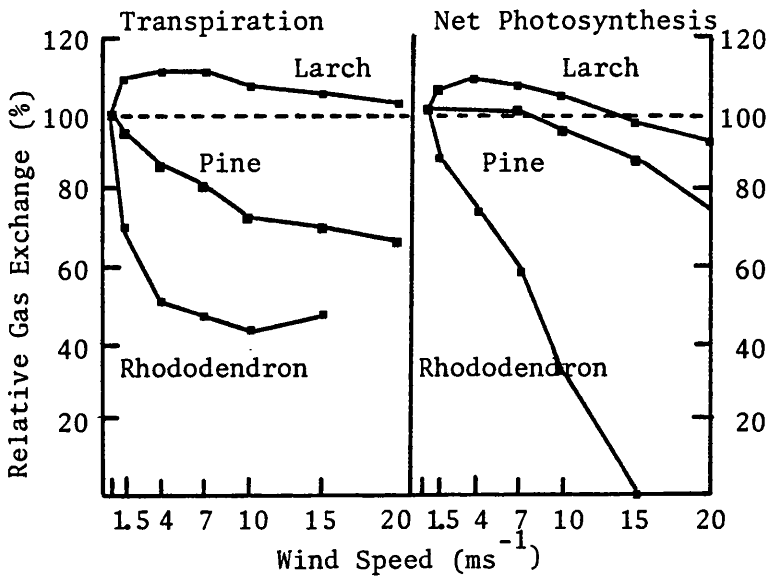
In addition to these most obvious forms of damage, plants constantly exposed to drying winds during the growing season may be incapable of attaining the degree of turgidity necessary to allow their expanding cells to achieve full size. Consequently the organs of the plant become dwarfed to a greater or lesser extent (Daubenmire 1974). Depending on the species concerned and the intensity of exposure, dwarfing may or may not be associated with obvious tissue damage, such as foliage bruising and shoot dessication. Shoot dessication gives rise to wind shaping, a familiar plant response, especially in coastal regions. The extent of these forms of wind damage are dependent not only upon the maintenance of above average velocities but on the moisture content of the air. Dessication damage is most devastating when air masses of low humidty are involved.

The consistently dry winds which plague Eastern England (Manley 1935) throughout the spring are a case in point, and for many woody species represent by far the most serious climatic limitation to growth in these areas.

The physiological impact of wind is less obvious to casual observers, but in many cases is far more important than the physical influences previously described. Through reducing the thickness of the leaves saturated boundary layer, wind increases the transpiration rate in many woody species, leading to stomatal closure and ultimately a fall in carbohydrate production. The transpiration responses of 3 species to increasing wind speed are illustrated in Fig 7.9

Fig 7.9 Effect of Wind on Transpiration and Photosynthesis of 3 Woody Plants at the Tree Line in the European Alps

(Adapted from Tranquillini 1970).



The Larch (Larix decidua) is typical of an arborescent species whose transpiration rate is little affected by wind velocity, although Bannister (1976) suggests that this may partly be due to mechanical leaf damage resulting in water loss independent of stomatal control mechanisms.

Larch can apparently behave in this manner, because it is either:

a) tolerant of high internal water deficits and therefore a degree of protoplasmic dessication

b) its natural distribution coincides with a soil moisture regime which can fuel its transpiration

The strategy of rapid stomatal closure adopted by the Rhododendron is typical of a species which grows only in sheltered locations.

Nobel (1981) states that _Rhododendron ferrugineum_ is a plant associated with sheltered ravines. It appears that woody species respond very differently to wind depending upon their ecological niche.

The strategies adopted by the Larch and probably other "exposure tolerant" species, allow the plant to maintain a high rate of photosynthesis and therefore growth even at relatively high wind velocities. _Larix decidua_ shows a photosynthetic maxima at a wind velocity of approximately 4.0 ms^{-1} compared with 0.5 ms^{-1} for _Rhododendron ferrugineum_ and 0.3 ms^{-1} for _Brassica napus_ (Wadsworth 1959).

This strategy may prove counterproductive when the plant is grown in cultivation in situations where soil moisture supplies and relative humidity are insufficient to prevent the development of damaging transpiration induced internal moisture deficits.

It is interesting to note that in the Forestry Commission review of the silvicultural requirements of _Larix decidua_ in England (Forestry Comm.1957) the author remarks "when however a none retentive soil is combined with low rainfall Larch fails to prosper". General observations on the performance of Larch support this by suggesting that this species is initially satisfactory but on dry sites becomes increasingly susceptible to decline with age.

This is possibly a direct consequence of the Larchs inability to control transpiration, and thereby avoid dessication damage. Species with a more conservative exposure strategy involving rapid stomatal closure, avoid dessication damage, but only at the expense of photosynthesis. Plants with these mechanisms are therefore likely to grow very slowly, if satisfactorily in exposure.

Air temperature also infuences plant tolerance of exposure, as a result of the convective cooling of plant leaves by wind. The temperature of an insolated leaf may be reduced by as much as 7 degrees centigrade by an increase in wind speed from 0.2 to 2.0 $m\ s^{-1}$ (Gates & Papian 1971), and this may further reduce the potential for photosynthesis and growth, especially in species for which temperatures in parts of England and Wales are already markedly sub-optimal.

In summary, plant response to exposure is a complex issue, and cultivated species vary greatly in their capacity to make satisfactory growth under such conditions.

In practice a species actual tolerance varies between sites depending upon the prevailing soil moisture status, relative humidity and air temperature. (Macdonald 1951). In general the physiological and physical - mechanical effects of exposure are most marked when associated with low humidities. (Odum 1979)

7.6.2 Quantification of Plant Tolerance of Wind

Most of the empirical knowledge of decorative plant performance derives from the gardening literature and information regarding plant tolerance to the levels of exposure experienced outside the garden environment is exceptionally scarce. Understandably, gardeners in exposed situations e.g coastal or upland regions have not accepted the status quo and selected plants for tolerance, but have drastically modified their environment by low diversity peripheral plantings of exposure tolerant species. This practice has always been an fundamental tenet of amateur horticulture and has produced splendid climatic curiosities such as Inverewe and Tresco, but little information on exposure tolerance.

The forestry planting site is often more comparable in terms of exposure, but the literature of forestry documents the response of only a few species, many of which are inappropriate to contemporary landscape design.

Logically the landscape design and contracting industry would be the ideal source of information, but sadly, few practitioners ever document their experiences in these matters.

Consequently the author has had to rely on fragments, information scattered throughout the literature, (Arnold Forster 1948, Caborn 1957, 1965, MAFF 1970, Bean 1973-80, Odum 1979), supplemented by his own observations of plant response to exposure in sites such as motorways and some of the collections documented in Table 7.2.

In addition to these difficulties, this topic presents problems of definition. The mean maximum values for exposure (in $m\ s^{-1}$) can be estimated for any area from meteorological records, (Met. Office 1952) but due to the overiding influence of local features such as buildings, vegetation and topography, these do not give any reliable indication of actual exposure at a given site.

In view of these difficulties, the location orientated classification which has been employed for other climatic parameters is not realistic. The exposure against which plant tolerance has been assessed approximates to the mean for lowland England and Wales, thereby corresponding to mean velocities of 4.5 - 5.5 ms^{-1} (Met. Office 1952). Using this as a basis for comparison, actual mean velocities will be higher on the western and eastern coasts and at altitude, and the plants response correspondingly more exagerated. These anomalies are brought to the users attention in Hortbases' User Handbook. In addition, where a plant is known to be extremely sensitive to the dry winds common in the eastern region in Spring e.g Robinia p. 'Frisia' this is pointed out via User-Limitations.

The plants response to this model of exposure may correspond to one of three levels of tolerance. This approach is summarised in Table 7.13.

Table 7.13 <u>Tolerance of Exposure Classification Used within Plantbase</u>

Tolerance Level	Species typically exhibiting this level of tolerance
High	Acer pseudoplatanus, Senecio 'Sunshine' Sorbus aria, Sorbus x intermedia, Pinus nigra
Average	Euonymus europaeus, Rosa sp., Viburnum sp.
Low	Robinia p. 'Frisia', Ribes speciosum, Acer palmatum, Euphorbia venata, Cornus alternifolia, Fatsia japonica

Species that are categorised as possessing high tolerance are those that grow satisfactorily in full exposure and are not regularly subjected to stunting, defoliation, foliage browning or shoot die back. Species in the low tolerance bracket can be expected to exhibit the above symptoms on exposed sites.

7.7 Plant Tolerance of Sub-Optimal Soils

Plantbase topics involved:

tol_comp_clay

tol_fr_dr_aggr

Irrespective of the scale of operation contemporary landscape is increasingly concerned with growing vegetation on sites that have been subjected to massive soil disturbance, and which range in traditional horticultural terms from sub-optimal to extremely hostile except in cases where the original top soil has been stripped and stored prior to the commencement of construction work. Compaction arising from site operations typically results in the planting substrate bearing little resemblance to the original soil profile.

In such cases both agricultural and geological classifications of soil type are of limited value. On Plantbase soils (growth substrates), are considered primarily in terms of their direct suitability to support plant growth, that is, the physical characteristics; (density, total pore volume, and pore diameter) and their chemical characteristics, rather than in terms of textural classes.

The history of the planting substrate is of great importance and Table 7.14 compares the effects of origin on a landscape substrates physical suitability for supporting plant growth.

In addition to some substrates being innately more satisfactory than others for plant growth, there are clearly considerable differences in the ease with which different substrates can be ameliorated to achieve this.

Given intelligent horticultural management plus amelioration where necessary, the first three categories of substrates in Table 7.14 are all potentially satisfactory for a wide range of decorative plants. In contrast, the latter categories, i.e the most hostile substrates are often associated with large projects, such as motorway developments and design constraints often require their acceptance as found. This in turn necessitates the use of species which can tolerate the prevailing conditions with little or no amelioration, an approach which has been adopted with some success by bodies such as the Department of Transport (Dunball 1978). The issues discussed in the preceeding paragraphs have resulted in a classification of planting substrates in which plant performance is assessed against only two substrates which represent the extremes of the continuum of landscape "soils". These are as follows:

Substrates in which particles of less than 0.002 mm diameter prevail, severely compacted, partially anaerobic, corresponding to a bulk density in excess of 1.5 $g\ cm^{-3}$, a pore volume of less than 35.0 % and with an air content at field capacity of less than 15.0 %. e.g compacted clays.

Table 7.14 Origins and Physical Suitability of a Typical Range of Urban Planting Substrates for the Growth of Decorative Plants

Origin of, and Characteristics of Planting Substrate	Suitability for Decorative Plant Growth
Original topsoil respread.(Stripped and stored prior to commencement of site works)	Potentially high depending upon original quality and storage method. Depth of respread layer and physical characteristics of underlying layers critical
Topsoil imported prior to planting as a result of scarcity, unsuitability or destruction of original topsoil	Variable, depending on source of supply. Many supplied topsoils are of extremely low quality (Bradshaw & Chadwick 1980). Depth of respread layer and characteristics of underlying layers again critical

Original topsoil left in situ and subjected to occasional traffic	Variable, depending upon extent of compaction and percentage clay fraction. Successful amelioration may be practical
Artificial topsoil derived from crushed brick rubble or equivalent	Potentially low due to poor water holding capacity, although can be successful if tolerant species are employed. Main advantage is absence of weed seed bank
Severely compacted and or denatured clay based topsoil or subsoil	Very low. The most difficult to vegetate due to high bulk densities and tendency to anaerobosis. Requires selection of extremely tolerant genotypes

Substrates in which particles in excess of 5.0 mm diameter predominate, excessively droughty, corresponding to a bulk density of less than 1.0 g cm^{-3}, a pore volume in excess of 55.0 % and an air content at field capacity in excess of 30.0 % and low nutrient storage and exchange capacity ,e.g crushed brick or rock.

Substrates possessing the above characteristics are,for opposing reasons hostile to the growth of many landscape plants. (Yelanosky 1963, Russell 1973, Patterson 1976, Sheldon & Bradshaw 1976, Richards 1979, Ruark, Mader & Tattar 1982, 1983)

Substrates which fall in between these two extremes can generally be made to be satisfactory for plant growth. Species requirements in terms of acidity-alkalinity are covered by the topic PH (see 7.8). Notice is given in User Limitations for fastidious species. The nutritional aspects of soils are not considered within Plantbase, as in most cases, these are readily manipulated and should not be a contributing factor to unsatisfactory plant performance.

Plant tolerance of these two substrate types is assessed for genotypes on Plantbase as follows:

High, satisfactory growth possible

Average

Low, satisfactory growth unlikely

No data available

As the practice of deliberately growing vegetation in such hostile substrates is relatively new, information on plant responses to these extremes is scarce, hence the category of no data available. Despite this the following sources have proved to be of value; Patterson 1976, Sheldon & Bradshaw 1976, Humphries & Bradshaw 1977, Buckley 1978, Chatto 1978, Department of Transport 1978, Dunball 1978, Carpenter & Hensley 1979, Hamilton 1979, Sukopp, Blume & Kunick 1979, Bradshaw & Chadwick 1980, Lowe & Ambrose 1981

Information derived from these literature sources has also been supplemented by field observations at a number of sites where such conditions prevail. Some of these are listed in Table 7.2.

7.8 Plant Response to Substrate pH

Plantbase topic involved:

ph

The following options are recognised on Plantbase:

acid to neutral (ph 3-7)

broadly neutral

neutral to alkaline (ph 7-10)

complete range (3-10)

The range in which a plant is considered to perform most satisfactorily in terms of general vigour and avoidance of pH generated mineral deficiencies is recorded on Plantbase.

7.9 Plant Tolerance of Air Pollution

Plantbase topic involved:

polu_tol

During the past decade air pollution, and especially that involving sulphur dioxide and smoke, has declined in many urban areas (Saunders & Wood 1977). The effects of pollutants upon plants may be classified as either acute or chronic. Acute responses involve tissue death as a result of exposure to high concentrations of pollutants or relatively low concentrations in the case of very sensitive plants. Chronic injury appears as a stress response and occurs when relatively tolerant species are exposed to low levels of pollutant. Pollution levels sufficient to induce recognisable visual symptoms in plants are now largely confined to locations adjacent to the source of the pollutant, be it, heavy industrial plant or congested urban highways. However, the absence of clearly recognisable visual symptoms in plants can be misleading, as most pollutants effecta marked reductionin the growth potential of plants at concentrations well below those necessary to induce visual symptoms.

These "chronic" effects occur as a result of pollutants interfering with stomatal closure, chloroplast structure, carbon dioxide fixation and electron transport (Mansfield 1976). An indication of just how widespread these "unseen" effects may be is demonstrated for cereals in Table 7.15. Whereas short term exposure to pollutants causes a reversible depression of photosynthesis in sensitive plants, long term exposure results in a significant depression of dry matter accumulation. Sulphur dioxide pollution is not equally detrimental to all plant species, and may even be beneficial to tolerant species growing on sulphur deficient soils (Davis & Gerthold 1976).

Table 7.15 Comparison of SO_2 and O_3 Concentrations (ppm) in Urban and Rural Locations with Threshold Values for Growth Reduction in Cereals (Adapted from Fitter & Hay 1981).

Pollutant	Conc. in rural areas	Conc. in urban areas	Conc. in indust. areas	Threshold for growth reduction
SO_2	0.001-0.05	0.02-0.5	0.001-1.0	0.2
O_3	0.02-0.06	0.08 -	0.25	0.05

Table 7.16 <u>Characteristic Woody Plant Response to Sulphur Dioxide and Ozone</u>

Plant type	Response to SO_2 Acute	Response to SO_2 Chronic	Response to O_3 Acute	Response to O_3 Chronic
Broadleaves	Interveinal leaf cells are killed resulting in necrotic lesions	Interveinal chlorosis	White, brown or yellow flecks in upper leaf surface (associated with stomata)	
Conifers	Tips of needles turn brown, in extreme cases entire needle turns brown	Chlorosis of part or all of needle. Premature abscission of older needles results in thin canopies	As for SO_2	As for SO_2

Most of the assessment of plant tolerance of pollution has been based upon visual symptoms of damage. In industrialised societies, the most important air pollutants are generally sulphur dioxide and ozone, the former from the combustion of fossil fuels and the latter from the photo-chemical decomposition of exhaust hydrocarbons. Halides, ethylene, ammonia, acids, dusts and heavy metals are pollutants which are commonly of local importance. (Davis & Gerthold 1976)

On Plantbase pollution tolerance is assessed on the basis of a species response to the levels of sulphur dioxide and ozone associated with Britains industrial cities.

The following levels of tolerance are recognised:

high

average

low

no data available

Species which are common in urban areas and which do not generally demonstrate acute symptoms are listed as high. Species which have been recorded as exhibiting acute symptoms are listed as low. With the exception of the small number of taxa that are either extremely tolerant or sensitive, the tolerance of the vast majority of Britains decorative flora remains an unknown.

This situation is complicated by the wide variation in tolerance within a genus at both the inter and intraspecific level, making generalisations hazardous or impossible.

In arriving at the assessments contained within Plantbase, the followingliterature sources have been used; Scurfield (1955), Wood & Coppolino (1971), Hillier (1974), Davis & Gerthold (1976), Saunders & Wood (1977). Where no information is available on the response of a species it is recorded as "no data available".

7.10 Plant Tolerance of Air Borne Salt

Plantbase topics involved:

salt_tol

In Britain this phenomenon may be encountered in the following situations;

a) sites adjacent to the coast
b) sites adjacent to roads to which de-icing salts are applied in winter

In both these locations the main problem is direct ionic toxicity following from the deposition of sodium chloride onto the aerial parts of the plant. In the latter location damage may occasionally occur following localised accumulation of salt in roadside soils, but in general this does not constitute a serious problem in Britain, with soluble salt concentrations generally remaining below the damage threshold of 2000 ppm. This is in sharp contrast to countries that experience a more continental winter, and consequently use far greater amounts of de-icing salts. In the Chichago region de-icing salts are applied at 45 tonnes per km of traffic lane resulting in localised roadside soluble salt concentration of 20,000 to 50,000 ppm. (Dirr 1976).

Such soils are incapable of supporting any vegetation other than halophytes.

Plants which can tolerate high soluble salt concentrations in the root zone do not necessarily tolerate foliage applications of salt. This is the case with <u>Thuja occidentalis</u>, whilst when dormant <u>Gleditsia triacanthos</u> tolerates air borne salt but not high soil concentrations (Dirr 1974).

The seasonality of exposure to salt spray is important, woody plants are most tolerant of air borne salt during the winter months when they are physiologically dormant. High wind velocities have been observed to have a synergistic effect and increase aerial salt damage (Moss 1939). Consequently the coastal location with its year round risk of airborne salt spray and above average wind velocities is the most trying of the environments.

When sodium chloride is deposited on the leaves and stems of plants , the constituent ions penetrate the cuticle and are incorporated into the plants tissues. Tolerance of wind blown sodium chloride correlates with the plants capacity to prevent ingress, and tolerant species are often characterised by thick waxy cuticles or other epidermal modifications.

The reduced sensitivity of dormant plants can be ascribed to the same factor. Once the chloride ion concentration reaches a threshold value in plant tissues, cellular adjustments to offset toxic effects appear not to exist. (Dirr 1974).

Chloride ions are considered by most workers to consitiute the toxic principal, and visual injury correlates closely with plant shoot chloride content (Dirr 1975).

The symptoms of aerial salt injury are as follows:

a) leaf browning and twig dieback especially on the windward side (lee side may be unaffected)

b) failure of buds on the exposed side

c) stimulation of massed epicormic growth

The tolerance of air borne salt spray recorded in Plantbase is based upon plant performance in coastal locations and roadside sites. Tolerance of winter de-icing salt spray is likely to be greater than is recorded within Plantbase.

The coastal zone in which tolerance of salt borne spray is an essential can generally be considered to extend inland for 1-3 km, depending upon local topography. Under severe gale conditions however, this zone may extend inland for 20 km or more (Evison 1957, Moss 1939), although on most of our coasts such occurrences are too infrequent to be of significant importance to an information system such as Plantbase.

On Plantbase the following levels of tolerance of airborne salt spray are recognised:

high, damage unlikely
average
low, damage probable
no data available

The last option recognises that for many decorative plants their responses to air borne salt spray are not known with any certainty. Plants recorded as "high" are those which show little or no damage, e.g *Griselinia littoralis, Ulex europaeus , Pinus nigra, and Quercus ilex*.

Plants designated as possessing low tolerance are represented by genotypes such as *Acer palmatum, Cornus florida* (Francis & Curtis 1979) *Fagus sylvatica, and Prunus serrulata*.

In addition to literature already cited and observations made in the coastal collections listed in Table 7.2, the following sources have also been consulted: Kelway (1962), Shepard (1962), Evison (1963), Menninger (1964), Buchsbom (1968, 1969), MAFF (1970), Dirr (1978), Pellet (undated)

7.11 Plant Tolerance of Stooling and Coppicing

Plantbase topics involved:

tol_coppice

The physical manipulation of decorative plants in the landscape has traditionally involved selective removal of tissues, often in order to maximise an aspect of display, frequently flowering, or alternatively to incorporate long term structural strength into the canopy (Brown 1972).

The simultaneous removal of the entire canopy to ground level has been reserved for those species possessing attractively coloured annual shoots e.g *Cornus alba, Rubus cockburnianus*. It is only comparatively recently that changes in landscape design have forced the reappraisal of stooling as a general technique for the management of woody plants.

Stooling and coppicing may be desirable in order to :

a) rejuvenate plantings whose canopies are no longer satisfying the physical or aesthetic functions for which they were originally selected

b) encourage newly planted material to produce vigorous vegetative growth as an aid to plant establishment (Baines 1982)

c) change the form of plants, e.g to create multi-stems of species which are only normally grown and marketed by the nursery stock industry as single stemmed plants. This is especially useful in situations where a less formal appearance is required.

d) increase the display impact of plants with coloured bark, e.g trees such as Betula pendula, Eucalyptus niphophila, Acer griseum.

Tolerance of stooling or coppicing correlates with the existence of dormant buds or the ability to initiate adventitious buds.

Dormant or epicormic buds are preformed vegetative buds which remain quiescent until they die or are stimulated into growth by the plant canopy sustaining severe damage. The decline in the capacity of mature plants to respond satisfactorily to stooling is probably associated with both a reduction in the number of viable dormant buds and their connections with the translocatory systems. (Kozlowski 1979)

The other potential source of regrowth are meristems which form irregularly in the older tissues of both roots and stems, but not in leaf axils. These are known as adventitious buds, and generally develop from undifferentiated tissues, especially callus. With the exception of shoots developing below ground this group of meristems are generally less involved in the stooling response than are those of the first category.

The nutritional status of the plant exerts a considerable influence on the form of canopy regrowth following this practice, and most species respond most satisfactorily under a high nitrogen regime. Frequent, i.e annual or biennial removal of the canopy may have serious consequences for the plants carbohydrate balance, and eventually lead to a decline in vegetative vigour.

Within Plantbase tolerance of stooling - coppicing is assessed on the basis of the plants biological capacity to initiate adventitious or activate dormant buds, and the form of and rate at which such regrowth proceeds.

The following classes of tolerance are recognised:

	Typical species showing this response
high..................	Corylus avellana
low	Cytisus beanii, Cistus x corbariensis, Ceanothus impressus
no data available	

The capacity of a plant to produce satisfactory regrowth following the removal of the canopy often decreases with age. On Plantbase the recorded tolerance is assessed for plants which have not yet entered the decline associated with the post maturity phase. Species which characteristically forfeit this capacity before they reach this age are noted in User-Limitations. The ability of otherwise tolerant species to respond satisfactorily to stooling and coppicing may also be adversely affected by nursery practices such as grafting. Where grafting is commonly used to produce a certain plant the Plantbase user is notified under Additional_Features.

As a relatively new management technique for amenity areas relatively little specific information on woody plant response is available. Consequently assessments are based on observations of recovery following canopy death in severe winters, supported by the traditional pruning literature, (Brown 1972), and the literature of stool bed management, (Congdon 1954). Species whose responses are not known with any certainty are listed as "no data available".

7.12 Plant Capacity to Self Adhere to Masonry

Plantbase topic involved:

attach_mason

Most woody climbing species attach themselves to surfaces or plants by means of twining stems, petioles, tendrils or hooked thorns. When grown against buildings these plants require the provision of a support system. On many landscape sites this is often not provided or is inadequate and if these species are employed failure results.

Accordingly self clinging climbing plants which can attach themselves to the wall surface without this provision, are of great value. Another advantage of self clinging species is their leaf patterns and overall canopy tracery are often more elegant than those of other climbers.

On Plantbase all plants (climbers and non climbers) are recorded as being either:

self adhering to walls
requiring the provision of support

Assessment of a plants ability to satisfactorily self cling is made in the context of a relatively rough masonry surface, e.g brick work or textured concrete. This reflects the varying capacity amongst self clingers to adhere to surfaces of varying roughness. Species which climb via aerial roots are only generally satisfactory on the surfaces mentioned, whereas species which rely on adhesive suckers such as Parthenocissus tricuspidata and P. henryana, can also adhere to timber and other relatively smooth surfaces.

The user of Plantbase is alerted via User Limitations to species which commonly require several years establishment prior to producing their means of attachment, e.g Hedera colchica, Hydrangea petiolaris, Pathenocissus quinquefolia.

Information on the self clinging ability of climbing plants has been drawn from the authors observations of plants in the collections listed in Table 7.2 supplemented by the literature (Pearce 1957, Lucas Phillips 1967, Prockter 1973).

7.13 Plant Leaf Fall Characteristics

Plantbase topic involved:

lf_fall

In urban areas autumnal leaf fall can represent a physical hazard to both vehicular and pedestrian traffic. This is especially so for tree species whose leaves are either mucilaginous at abscission or become so soon afterwards, e.g Tilia species. Accumulations of fallen leaves are also responsible for the destruction of mown turf in areas sheltered from the wind.

All of these problems are exacerbated when maintenance resources are limited, but can be avoided to some extent by careful plant selection.

On Plantbase taxa may be classified as being:

problem
average
no problem

Species recorded as presenting no problem are generally those with very small leaves or leaflets that either decompose rapidly or alternatively decay very slowly, remaining "dry", and not accumulating readily.

7.14 Plant Ability to Tolerate Vandalism

Plantbase topic involved:

vandal_tol

The interaction of people with planted vegetation in public open space inevitably results in some plants sustaining damage. This damage may be either unintentional or deliberate, and although in some locations vandalism may pose a considerable problem, its importance is sometimes over exaggerated.

It is not unreasonable to suggest that as many or more plantings of woody plants fail due to the negligence of maintenance authorities in controlling weed competition than through public vandalism. Assuming vandalism does pose a substantial threat, strategies which help maximise the possibility of success must be considered.

Firstly, it must be recognised that all newly planted woody plants, irrespective of growth rate, branch flexibility, supporting structures such as stakes and protective structures such as thorns, are extremely vunerable to premeditated vandalism. This remains the case until their root systems have anchored them securely into the planting substrate. With the exception of semi mature and mature trees, in the first year of a planting indirect methods of avoiding damage such as community involvement in planting, (Young 1978) protective fencing, and phasing of planting to minimise conflicts, must be investigated.

Only after this period can a species specific characteristics be realistically expected to improve or lessen its chance of survival. Traditionally it has been felt that the use of thorny plants could dissuade deliberate vandalism. It is proposed that this is a very narrow concept and a more realistic approach is to include plants which are biologically capable of rapid recovery following damage.

On Plantbase the following plant related factors are considered to be important in combating vandalism:

a) Selection of vegetation which will rapidly produce new growth in reponse to damage. (See 7.11) Vigorous suckering thicket formers such as Rubus cockburnianus are especially resistant

b) Maximisation of early growth via husbandry inputs, especially weed control and nitrogen application. Public respect for vegetation frequently seems to correlate with the size and apparent prosperity of the component plants. In addition to these psychological factors, vigorously growing plants have the capacity to recover rapidly should damage occur.

As has already been stated, in the first year of planting survival of vandalism is largely independent of plant characteristics. Plantbases assessment of a genotypes ability to tolerate vandalism therefore applies only to plants which have been established in the landscape for a minimum period of one year.

The following levels of tolerance are recognised:

high
average
low

Genotypes assessed as high are likely to possess one or more of the following:

Vigorous growth coupled with the abiliity to replace damaged organs, flexible non brittle branch structure, dense growth and or protective structures such as thorns.

Species which are typically produced via grafting are generally recorded as low, as damage frequently activates dormant buds on the rootstock.

7.15 Plant Tolerance of Selective Herbicides

Plantbase topics involved:

herb_pre_est_dich

herb_pre_est_len

herb_pre_est_prop

herb_pre_est_sim

herb_est_dich

herb_est_gly

herb_est_len

herb_est_prop

herb_est_sim

In terms of facilitating vegetative growth, elimination of weed competition is probably the most important husbandry imput.

Newly planted woody plants are particularly sensitive to weed competition, Davidson (1982) cites a 60% reduction in extension growth for plants growing in a weedy as opposed to a weed free environment. Differentials of a similar magnitude are reported by many other workers. (Messenger 1976, Nielson & Wakefield 1978, Fales & Wakefield 1981, Whitcomb 1981, Insley 1982).

Most workers agree that reduction in available soil moisture is the primary cause of weed induced growth depression. (Dancer 1964, Stott 1976).

Traditionally repeated surface cultivations have enabled a high standard of weed control to be achieved in landscape plantings. However to be successful this technique must be repeated at frequent intervals to ensure that weeds are destroyed whilst still very small. Given the current situation in which the time devoted to post-planting maintenance is limited, or in some cases almost non existent, new techniques are required which better fit a pattern of infrequent maintenance inspections.

As a result of their ability to suppress weed seed germination for periods of up to several months, residual herbicides slot very comfortably into a contemporary low maintenance profile, yet still allow for the maintenance of high standards of weed control.

Of the many herbicides now available the following have been selected as being familiar and efficacious:

Glyphosate

Dichlobenil

Lenacil

Propyzamide

Simazine

With the exception of Glyphosate these are all essentially residual soil acting, seed germination inhibitors, although at higher rates Dichlobenil and Propyzamide are effective eliminators of certain established perennial weeds. As a highly active, non selective herbicide Glyphosate may seem to be a suprising inclusion. However, on certain woody genera such as Hedera and Juniperus this material can be used as a selective if applied as an overall application in early autumn. (Bing 1977, Gouin 1977, Dunwell, Boe & Lee 1978). This herbicide is included in Plantbase as it has considerable future potential as an agent in the restoration of weed infested plantings of woody species.

Decorative plant tolerance of residual herbicides is based upon two major interactions: (Fryer & Makepeace 1977a)

a) Innate physiological tolerance, i.e a capacity to detoxify the active principal

b) Tolerance through physical avoidance in space and time, i.e failure to contact and or absorb the active principal

In addition to these basic sources of tolerance, avoidance of damage is also affected by age, size and degree of plant establishment, the concentration of herbicides and the soil type in terms of clay and organic fractions. Application rates that severely damage newly planted material will frequently fail to produce any visible ill effects in established plants of the same species. Because of this differential response, on Plantbase herbicide tolerance is assessed for both:

a) The "pre-establishment" period, i.e tolerance of herbicides applied immediately after planting.

b) The "post-establishment" period, i.e tolerance of herbicides applied to plants that have been planted in the landscape for at least 1 year.

Table 7.17 summarises the herbicide application rate thresholds in relation to the degree of establishment and soil type against which plant tolerance has been assessed.

The following classes of tolerance are recognised on Plantbase:
safe
limited damage possible
damage probable
no data available

Although a wealth of experience of the responses of decorative plants to residual herbicides exists within horticulture and the nursery stock industry in particular, very little of this information has been published.

These comments apply equally to the herbicide manufacturers who faced with the constant threat of litigation are reluctant to produce specific recommendations for a wide range of decorative plants. (D'Souza 1981).

Consequently, amongst landscape practitioners knowledge of the herbicide tolerances of decorative plants has increased only very slowly despite increasingly common usage of these materials. The information that is

Table 7.17 Application Rate Thresholds in kg/ai/ha Against which Plant Tolerance has been Assessed

Establishment Phase	Herbicide	Soil Type: Low in Clay & Organic Fractions	Soil Type: High in Clay & Organic Fractions
Pre-establishment	Dichlobenil	4.0	4.0 [1]
	Lenacil	1.8	2.7
	Propyzamide	1.7	1.7 [2]
	Simazine	1.1	1.7
Post-establisment	Dichlobenil	6.7	9.2 [2]
	Glyphosate	2.2	2.2 [2]
	Lenacil	1.7	3.4
	Propyzamide	1.7	1.7 [2]
	Simazine	1.7	2.2

1 Relatively unaffected by soil type

2 Achieve good control of certain established perennial weeds

available, is generally fragmentary, and is scattered throughout the literature. The following are some of the sources used in making the assessments:

Robinson (1976), Robinson & Kelly (1976), Elmore et al (1977), Fryer & Makepeace (1977b), Hillier (1977), Devoy (1978a,b), Robinson (1978), Ahrens (1979), PBI (1981), Duphar Midox (undated), Robinson (1981)

The information extracted from these sources has been supplemented by the results of a questionnaire circulated to commercial growers of open ground trees. (See Table 7.2) Even so for many decorative taxa no positive information is available and on Plantbase the tolerances of these plants are recorded as "no data available".

7.16 Aesthetic Life Span

Plantbase topic involved:

aesth_life

In addition to a woody plants characteristic biological life span, for many, largely non arborescent species, an aesthetic life span of much shorter duration is also identifiable. In such species increasing age beyond an often well defined point results in a reduction in elegance or value in the landscape.

Although primarily a function of the genotype, aesthetic life may be prolonged or shortened by the suitability of the environment, the planting density, and the level of cultivation.

A concept of aesthetic life is especially relevant in plantings composed of several species where it is important that the components should mature relatively evenly in order to avoid a situation in which short lived species are in decline whilst adjacent species are approaching the peak of their aesthetic worth.

Aesthetic life is not a concept which figures strongly in traditional garden based decorative horticulture. The appreciation of overmature specimens is typically associated with oriental landscape design. Its tolerance in western gardens is possibly associated with the plantsmen/collectors outlook in which the "head count" typically outweighs design considerations.

This approach is however inappropriate to contemporary landscape. In these sites appropriate, cost effective action must be taken as soon as plants begin to enter the aesthetic decline stage.

Depending upon a genotypes characteristics and location in the landscape the most satisfactory course of action may be either:

a) Regeneration of the canopy by stooling as in the case of tolerant vegetation such as <u>Mahonia aquifolium</u>

b) Removal followed by replanting with young stock. This is the only option for taxa that are incapable of regeneration via stooling e.g. Cytisus species and cultivars.

For the purposes of Plantbase, aesthetic life span is defined as the characteristic normal span of decorative life before replacement, or if feasible, before regeneration via stooling or coppicing is required.

The following classes of aesthetic life span are recognised:

less than or equal to 5 years

5-10 years

10-20 years

greater than 20 years

7.17 Maintenance Demand

Plantbase topic involved:

mainten_input

This topic attempts to provide the user with an indication of the post-establishment maintenance input necessary to maintain the aesthetic qualities for which a plant was initially selected.

In arriving at ratings for individual species factors such as pruning requirements, susceptibility to weed invasion (for low growing subjects),susceptibility to pests and diseases and leaf fall characteristics have been considered.

The following classes of maintenance demand are recognised on Plantbase:

high

average

low

Plants recorded as high are those which require inputs such as selective annual pruning, as in the case of Hybrid Tea Roses. Conversely, plants whose pruning requirements can be met mechanically by mowing via heavy duty rotary mowers or flails, are listed as average e.g. Hypericum calycinum. Only the most trouble free landscape plants such as Symphoricarpos 'Hancock' are listed as low.

7.18 Ease of Cultivation

Plantbase topic involved:

cultiv_ease

This topic involves a highly subjective assessment of a plants ability to produce a satisfactory phenotype in response to the suite of often suboptimal conditions associated with many landscape sites. The object of this topic is to give a general indication of the characteristic frequency of success of taxa in the landscape.

The following categories of cultivation ease, or ability to succeed are recognised:

difficult
average
easy
very easy

These categories represent only a relative judgement of a plants capacity to succeed. Plants listed as difficult may in fact be easy given suitable amelioration of the planting substrate and the provision of some shelter from wind. For example *Acer palmatum* is not an unduly difficult plant to grow in a garden but would be recorded as difficult on Plantbase.

7.19 Primary Role in the Landscape

Plantbase topic involved:

horti_func

Although some plants are equally satisfactory in widely divergent landscape roles, e.g. Hedera helix cultivars as self clinging climbers or ground cover, for the majority of taxa a combination of factors such as growth characteristics, overall form, maintenance requirements, environment, availability and cost, limit the roles in which they may be intelligently employed.

The objective of this topic is to provide the user with a guide to the role within contemporary landscape which will allow the potential of a plant to be fully realised.

On Plantbase the following roles are recognised:

aquatic

barrier plant

ground cover (including shrub massing less than 1m tall

shrub massing

shelter belt (woodland or urban forest)

specimen plant

turf component

wall plant (including climbers)

7.20 Tolerance of Planting Depth

Plantbase topic involved:

pltng_depth

This topic considers the most satisfactory planting depth for bulbs and corms.

The following options are recognised:

0-5 cm

5-10 cm

10-15 cm

15-20 cm

The above classes refer to the depth of soil over the apex of the planted bulbs. On heavy soils many bulbs and corms are best planted at the shallower end of the range indicated.

7.21 Water Depth for Aquatic Plants

Plantbase topic involved:

depth_water

This topic refers to submerged aquatics and marginals, many of which have specific tolerance ranges outside which they are difficult to establish.

The following categories are recognised on Plantbase, and refer to the maximum permissible depth of water over the rhizomes.

0-5 cm

5-15 cm

15-30 cm

30-60 cm

60-90 cm

7.22 Factors Limiting Plant Usage in the Landscape

Plantbase topic involved:

user_lim

The objective of this topic is to act as a fail safe and alert the user of the system to a plants deficiencies prior to a final selection decision.

Important limitations which are not or cannot be adequately documented by other Plantbase topics are stored as a written statement 60 characters long.

e.g For Genista aetnensis: "may exhibit root instability, not very attractive when young"

7.23 Additional Features

Plantbase topic involved:

add_fturs

The purpose of this topic is to provide information and comments on subjects not conveniently covered by the other topics of Plantbase. "Additional features" are contained in a 60 character long written statement, e.g for the plant Symphoricarpos x chenaultii 'Hancock':

"Probably the most functional woody ground cover but also good visually".

The user is advised in the systems handbook to check both User Limitations and Additional Features before finalising a selection decision.

7.24 Height and Width of Mature Specimens in Britain

Plantbase topics involved:

height

width

This is an assessment of the width and height of the canopies of species at maturity growing under average conditions. This assessment does not attempt to reflect the exceptionally large specimens associated with optimal climatic and edaphic environments, but the dimensions likely to be attained under the less ideal conditions of the landscape site. Height and width are recorded on Plantbase in centimetres up to a maximum of 9,999.

In addition to field work at some of the collections listed in Table 7.2 the following sources have been consulted in making these assessments:

Elwes & Henry (1906), Forest Comm. (1957), Bean (1973-1980), Mitchell (1974, 1975)

7.25 Height and Width After 10 Years Growth

Plantbase topics involved:

height_10

width_10

This topic is intended to give the user an impression not only of the quantity of extension growth produced in the first 10 years under landscape conditions but also of the proportions of the plants canopy in relation to its characteristic form at maturity.

These 2 topics reflect average performance, the performance of a plant in a given site may vary considerably from the values given in Plantbase depending upon suitability of the planting site environment and the size, age, and form of the planting material.

Often initial size differentials between various forms of planting material e.g standard tree versus seedling transplants, will in many cases even out resulting in the smaller more vigorous seedling overtaking the less dynamic standard tree within 10 years of planting. (Dunball 1978, Whalley 1979)

These topics are most valuable as a means of assessing the relative growth rates of different genotypes during their first 10 years in the landscape. The units of this assessment are centimetres and the permissible range is 0 - 9,999.

7.26 Annual Extension Growth of Woody Plants

Plantbase topic involved:

growth_woody

The actual growth rate of a taxon is largely determined by four interactive factors; the suitability - hostility of the planting site environment, the genetic potential of the planting material, its previous nursery treatment and the quality of planting and post planting husbandry. Most woody plants conform to the typical biological model of a sigmoidal growth curve. They exhibit vigorous growth in youth which gradually levels out and gives way to the stable, but limited extension growth of maturity (Harris 1983).

The duration of the phase of vigorous extension growth varies between species, in some only lasting for 2 to 5 years, in others, as in the case of *Sequoiadendron giganteum* 20 to 30 years (Mitchell 1975). As growth during this phase may largely determine the long term success of a plant in the landscape, Plantbases assessment of growth potential relates to this period in the plants life cycle. Average values have been assumed for the factors noted above.

Accordingly, in practice a plant may deviate considerably from the performance suggested. This will be especially likely following vigour promoting inputs such as heavy pruning, irrigation and nitrogen application.

Growth is recorded as average shoot extension per year in centimetres, and for trees largely refers to apically dominant shoots. In the case of shrubby plants it is primarily lateral growth that is assessed, although this will vary according to the predominant direction of growth.

On Plantbase the following categories of extension growth are recognised:

slow	less than or equal to 15 cm year
moderate	15-60 cm year
vigorous	60-90 cm year
v.vigorous	greater or equal to 90 cm year

Species prone to deviate from the typical growth curve are brought to the users attention in User Limitations. This is the case with species such as Hydrangea petiolaris, and Schizophragma hydrangeoides, which are regularly cited in the literature as being fast growing. In actual fact these species are extremely slow growing when young and only grow rapidly after they are well established in a suitable site, hence they are not suitable for sites where rapid initial growth is a priority.

7.27 Annual Extension Growth of Herbaceous Plants

Plantbase topic involved:

growth_herb

As for woody plants, this topic considers "average" performance under typical landscape conditions. As most herbaceous plants undergo an annual cycle of canopy abscission and regrowth, on Plantbase growth is assessed as the annual extension of the foliage canopy periphery, in centimetres, from the outermost portions of the previous seasons leaf bases and resting buds.

The following categories of growth are recognised on Plantbase:

slow	less than or equal to 15 cm
moderate	15-30 cm
vigorous	greater than or equal to 30 cm

7.28 Leaf Size

Plantbase topic involved:

lf_size

This topic documents the size of a plants leaves in terms of the distance between the leaf apex and basal junction with the petiole. This assessment is made in the context of the mature leaves of established plants growing under conditions adjudged to be satisfactory for the performance of that genotype.

On Plantbase the following categories of leaf size are recognised:

very small	less than or equal to 1 cm
small	1-5 cm
medium	5-20 cm
large	20-60 cm
very large	greater than or equal to 60 cm

This assessment does not differentiate between compound and entire leaves.

7.29 <u>Density of Foliage Canopy</u>

Plantbase topic involved:

density

Foliage canopy density is very rarely a uniform characteristic throughout the life span of a plant. It varies not only in response to age but also to environmental stresses such as those imposed by soil moisture deficits and localised shading. These particular stresses may either increase or reduce foliage density, depending upon the physiology of the species in question.

On Plantbase foliage canopy density is assessed for plants in the mid range of their aesthetic life, growing in satisfactory soil moisture and light regimes. Taxa likely to deviate dramatically from the documented foliage density are brought to the users attention in User Limitations.

For ease of interpretation density is assessed, irrespective of form, in terms of the extent to which the foliage density obstructs view through the canopy. The following categories of foliage density are recognised:

Total obstruction of view			e.g x	*Cupressocyparis leylandii*
Partial	"	"	e.g	*Pinus sylvestris*
Little	"	"	e.g	*Genista aetnensis*

7.30 Plant Form

Plantbase topics involved:

form

lf_shape

lf_margin

s_diam

In the context of Plantbase "form" is used to describe the overall shape of both whole plants and parts of a plant.

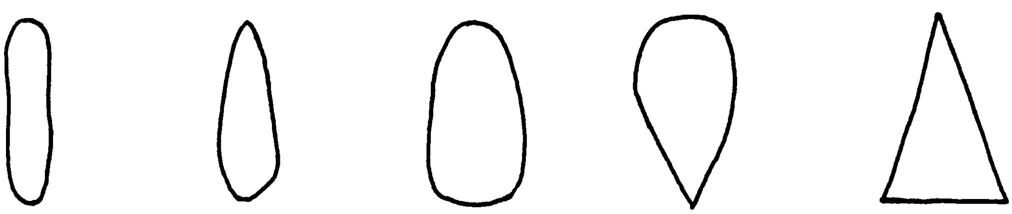
a) Overall Plant Form

Plantbase topic involved:

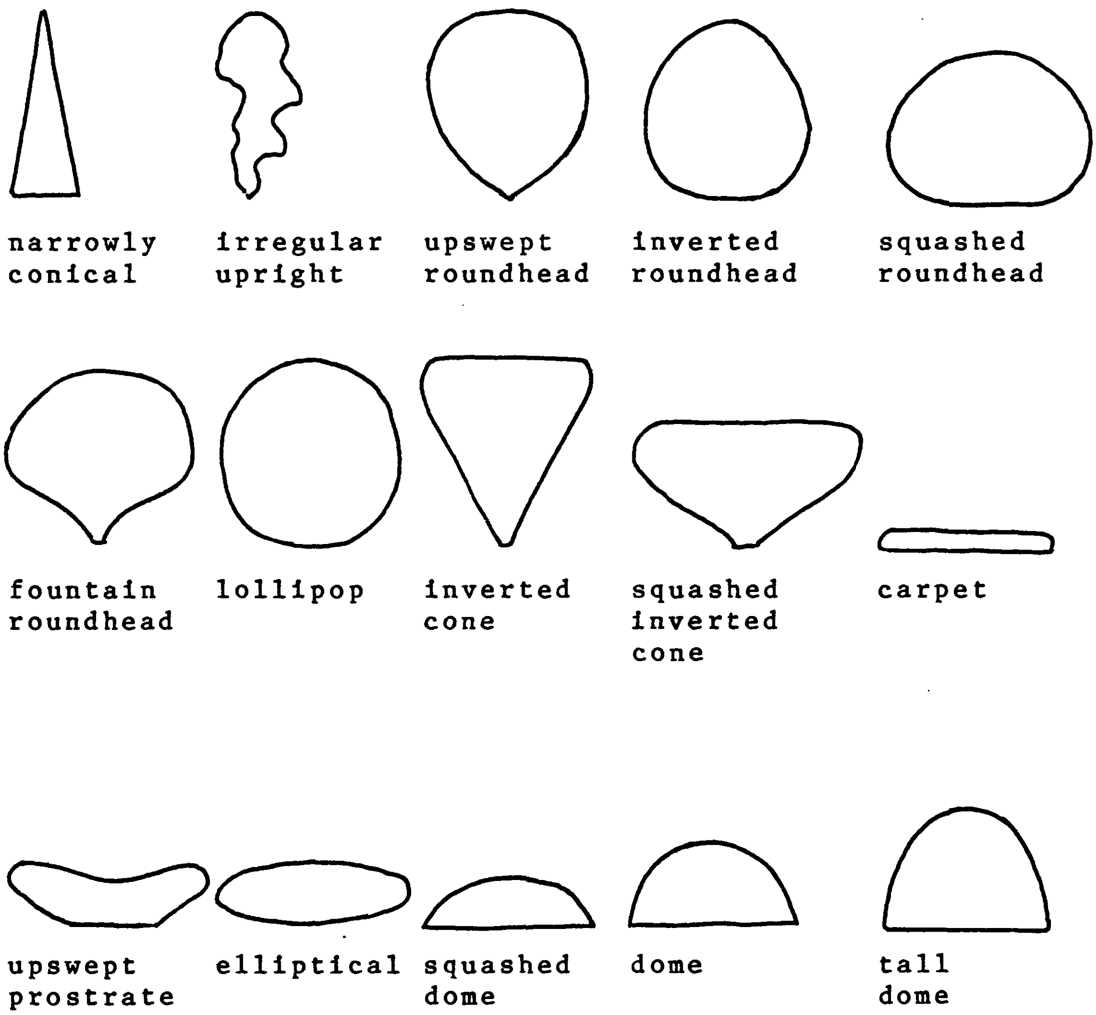
form

This topic records the overall shape of a plants foliage canopy. In order to facilitate interpretation of the various plant forms recognised within Plantbase, the adjectival or descriptive terms employed are supplemented in the User Handbook by silhouette line drawings. The presence or absence of a trunk is disregarded when assessing form.

The following plant forms are recognised within Plantbase:



narrowly fastigiate | conical fastigiate | broadly fastigiate | upswept fastigiate | conical



submerged aquatic   climbing

Taxa are ascribed to the most representative option.

b) Leaf Shape

Plantbase topic involved:

lf_shape

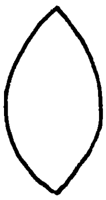
The following leaf shapes are recognised on Plantbase.

absent,
reduced
or scale

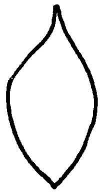
linear
filiferous

lanceolate

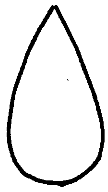
oblanceolate



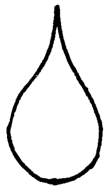
elliptical



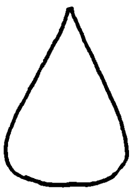
elliptical
acuminate



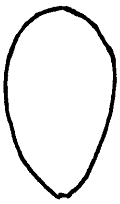
ovate



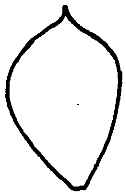
ovate
acuminate



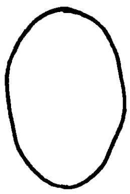
deltoid



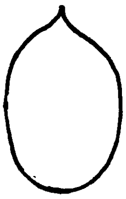
obovate



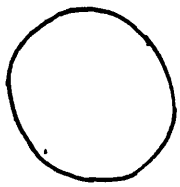
obovate
acuminate



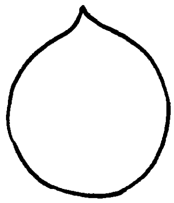
oblong



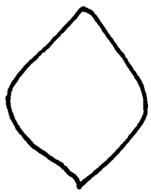
oblong
acuminate



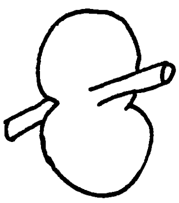
orbicular



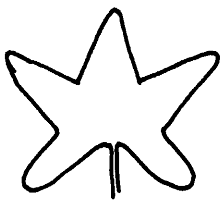
orbicular
acuminate



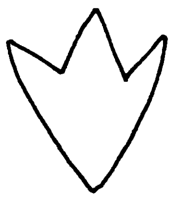
rhomboidal



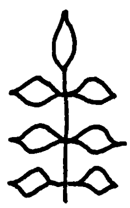
perfoliate



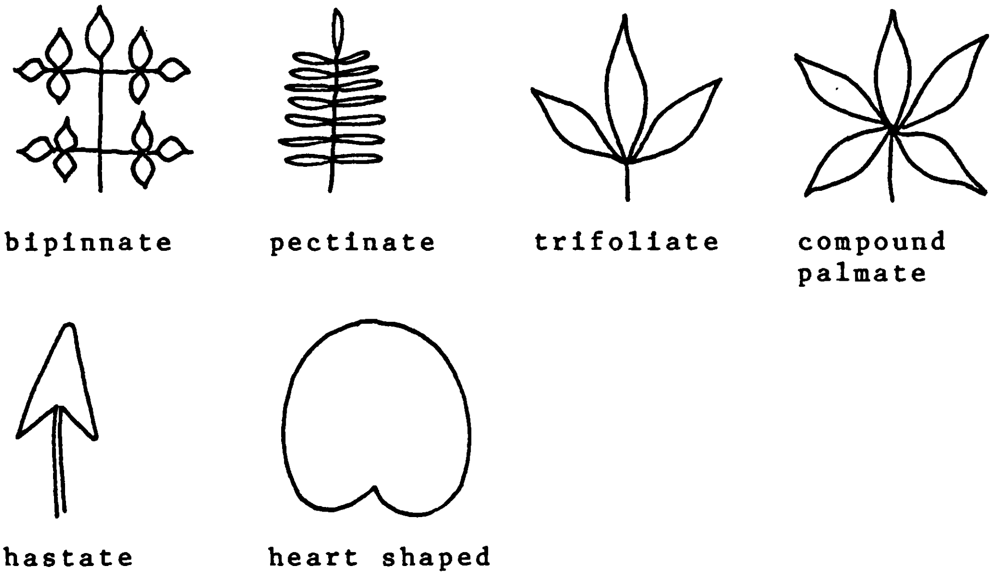
palmate
5-7 lobes



palmate
2-3 lobes



pinnate



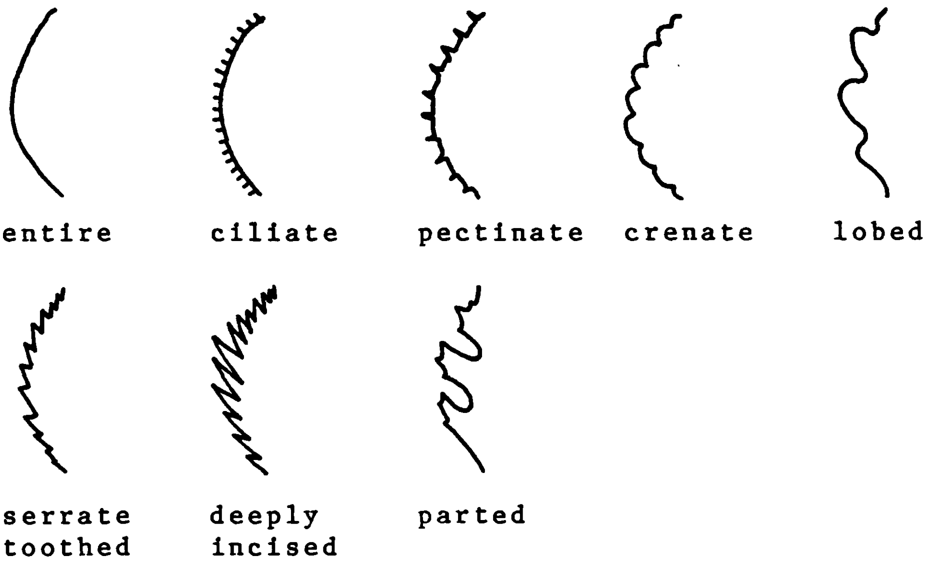
The assessment of leaf shape on Plantbase takes no account of petiole characteristics.

c) <u>The Leaf Margin</u>

Plantbase topic involved:

lf_margin

On Plantbase the following leaf margins are recognised:



This topic is used to qualify overall leaf shape on occasions when very specific selection criteria are demanded. For example if a diffuse,feathery foliage canopy was desired it is possible to select vegetation on the basis of pinnate leaves with deeply incised margins.

d) Stem Thickness

Plantbase topic involved:

s_diam

On Plantbase the following categories of stem thickness are recognised:

thick

average

thin

Stem thickness is assessed relative to overall plant size for stems of 3 years or younger.

7.31 Plant Texture

Plantbase topics involved:

text

tracery

s_text

b_text

lf_text

Within Plantbase plant texture is used to describe a structural three dimensional image of a plant or parts of a plant, which results from the interaction of form with the spatial arrangement of constituent parts.

When considering the whole plant, an assessment of overall texture makes it necessary to resort to somewhat abstract, subjective descriptions. Such difficulties are common to all texts which consider these issues e.g Hackett (1979), but largely disappear when assessing the component parts of the plant in isolation.

a) Overall Plant Texture

Plantbase topics involved:

texture

This topic attempts to describe the texture of the plants foliage canopy and the following categories are recognised:

compact smooth
compact angular
compact billowing
compact arching
compact feathery
open arching
open angular
open billowing
open feathery

semi pendulous

pendulous

spiky grasslike

spiky rosette

tabular

asymmetrical open angular

Except where stated the textural options are assumed to be asssociated with plant canopies that conform to normal precedents of symmetry.

b) Branch and Shoot Texture

Plantbase topic involved:

tracery

As the branch and shoot tracery is generally only evident for deciduous plants during the dormant season, most evergreen plants are excluded from this assessment. Evergreen exceptions to this are plants which maintain an extremely open or sparse foliage canopy as in the case of many Eucalyptus species.

On Plantbase the following categories of tracery are recognised:

stiff upright

stiff pendulous

stiff sparsely branched

stiff tortuous

stiff typical decurrent

relaxed upright

relaxed sparsely branched

relaxed tortuous

relaxed typical decurrent

relaxed twiggy

typical decurrent

typical excurrent

tabular

c) <u>Stem Texture</u>

Plantbase topic involved:

s_text

On Plantbase stem refers to shoots younger than or equal to 3 years old.

The following options are recognised:

fibrous

lenticular-warty

pubescent-hairy

rough-corky

shaggy-exfoliating

smooth

thorny

d) Bark Texture

Plantbase topic involved:

b_text

This assessment of texture refers to the mature bark which may characteristically be developed after anything from 3-4 years, in some Betula and Eucalyptus species to 15-20 years in genera such as Carya.

On Plantbase the following options are recognised:

plated-scaly
rough-corky
exfoliating-shaggy
smooth
warty-smooth
thorny
furrowed

e) Leaf Texture

Plantbase topic involved:

lf_text

Texture is assessed for the dorsal surface of mature leaves. On Plantbase the following options are recognised:

rough (i.e prominent venation)
smooth
hairy

7.32 Colour of Plant Parts

Plantbase topics involved:

s_col	s_col_qual
b_col	b_col_qual
lf_col_spr	lf_col_qual_spr
lf_col_sum	lf_col_qual_sum
lf_col_aut	lf_col_qual_aut
lf_col_win	lf_col_qual_win
lf_col_vent	lf_col_qual_vent
fl_col	fl_col_qual
fr_col	fr_col_qual

The range of colours associated with the organs of plants is extremely wide, and is further extended by the colour patterns resulting from the distribution of two or more adjacent colours.

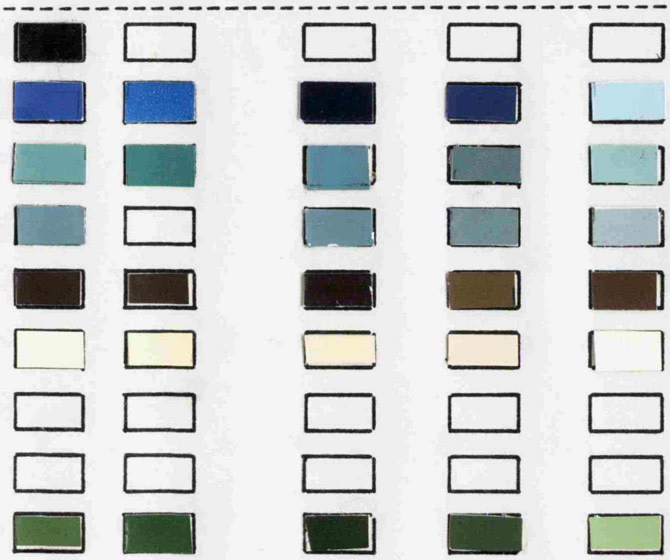
In the literature, with the exception of listings of plants nominated for horticultural awards and an occasional author (Haworth-Booth 1972), descriptions of the colour of plant parts have not been referenced to a standard colour chart. This tradition has the advantage of convenience, but at the same time suffers from the disadvantage of relying heavily on both the authors' and readers perception of colour.

In order to minimise this reliance on individual perception, within Plantbase the colour of plant stems, bark, dorsal leaf surfaces in spring, summer, autumn, winter, ventral leaf surfaces, flowers, and fruit, have been assessed against the colour chart illustrated in Fig 7.10. This colour chart uses colours selected from the Royal Horticultural Societies Colour Chart (Royal Horticultural Society 1966). The colour of some plant parts and leaves in particular varies considerably over the course of a year, and consequently leaf colour has been asesssed for each of the four seasons.

As can be seen from Fig 7.10 base colours can also be expressed as a tonal range. This qualification of basic colour is achieved by the accompanying colour qualification topic (col_qual). In addition to describing tonal deviations from the basic colour, the qualification topic can also be used to describe the pattern of colour distribution. e.g green and white stems may in addition be described as banded, bloomed, mottled or striated.

Fig 7.10 <u>Plantbase Colour Chart: Base Colours and Extended Tonal Range</u>

Base Colour and Plantbase Retrieval Code:			Plantbase Colour Qualifiers: Bright(a)	Dark(b)	Dull(c)	Pale(d)
Black	1					
Blue	2					
Blue-Green	3					
Blue-Grey	4					
Brown	5					
Cream	6					
Cream/Brown	7					
Cream/Grey	8					
Green	9					



Green/Cream	10
Green/Yellow	11
Green/White	12
Green/Grey/White	13
Green/Pink/White	14
Grey	15
Grey/Black	16
Grey-Brown	17
Grey-Green	18
Grey/Orange	19
Orange	20
Orange-Brown	21
Orange-Pink	22
Orange-Red	23
Orange-Yellow	24
Pink	25
Pink-Red	26
Purple	27
Purple-Red	28
Red	29
Violet	30
Violet-Blue	31
Violet-Pink	32
Yellow	33
Yellow-Brown	34
Yellow-Green	35
Yellow/Red	36
White	37
White/Blue	38

White/Grey	39					
White/Orange	40					
White/Pink	41					
White/Red	42					
White/Violet	43					
White/Yellow	44					

- Indicates a blending of two colours

/ Indicates the two colours exist as distinct entities

The colour pattern qualifiers recognised for each plant organ are summarised in Table 7.18

Table 7.18 <u>Colour Pattern Qualifiers of Plantbase</u>

Stem	Bark	Leaves	Flowers	Fruit
banded	banded	mottled	bicoloured	bicoloured
bloomed	mottled	suffused	mottled	bloomed
mottled	patchwork	striated	striped	mottled
striated	striated	variegated	suffused	suffused

The colour assessments recorded on Plantbase are largely based upon field work carried out in the collections listed in Table 7.2. The mass of data resulting from this exercise has been used as a reference point to guide colour assessments of plants for which neither data nor specimens were available at the time of data transcription.

7.33 Plant Scent

Plantbase topics involved:

lf_scent

fl_scent

Although many or all of the parts of the plant may be scented, or at least emit a scent in response to abrasion, on Plantbase only leaf and flower scent are recorded. Taxa which stimulate the olfactory senses in other ways are brought to the users attention via Additional Features, e.g the burnt sugar aroma emitted by the abscissing foliage of Cercidiphyllum japonicum.

The volatile oils responsible for leaf scent are generally only liberated upon handling and this is the criterion upon which the presence or absence of leaf scents has been assessed.

Conversely, flower scent is assessed at a distance of 1 m from the plant in the absence of handling under still conditions. The categories of leaf and flower scent recognised on Plantbase are as follows:

Leaf scent:

present

absent

Flower scent:

strong

moderate

none

Plants whose flowers are sufficiently fragrant to be discernable at distances in excess of 5 metres are noted under Additional Features. The information upon which plants have been categorised is derived from the authors field notes supported by the gardening literature (Genders 1977).

7.34 Plant Reflectivity

Plantbase topics involved:

s_reflect

lf_reflect

These topics record the capacity of plant stems and dorsal leaf surfaces to reflect incident light, and are therefore primarily concerned with the degree of cuticular waxiness, although for stems, colour may also be important, and light coloured stems have been recorded as being reflective.

The options for reflectance on Plantbase are as follows:

Stem reflectivity:

above average

average and below

Leaf reflectivity:

high

average

low

The two scales of assessment used mirror the differing range of reflectivity occurring in stems and leaves. Information for these topics has been derived from the general horticultural literature (Bean 1973-1980) supported by the authors field assessments.

7.35 Plant Duration of Display

Plantbase topics involved:

fl_period

fl_duration

fr_persist

Information on the duration of the flowering and fruiting display appears only sporadically in the horticultural literature, despite being of considerable value when selecting or evaluating a decorative plant. This is particularly the case when attempting to achieve specific colour effects, a continuity of display, or provide a display to coincide with the demands of a specific client group. These topics have necessitated that data be assembled via field observation.

a) Commencement of Flowering

Plantbase topic involved:

fl_period

The date on which flowering actually commences varies considerably depending upon the prevailing weather and the region of England and Wales under consideration. Flowering dates are generally determined by air and soil temperatures (Lindsey 1963) and may vary both from year to year and also from area to area. Specimens in Northern England may flower up to 1 month later than the same taxon in Southern England and up to 2 months later than in South Western England.

The rating given on Plantbase is by necessity a median one and represents typical performance in Southern England.

The following options are recognised for flowering date:

January

February

March

April

May

June

July

August

September

October

November

December

b) Duration of Flowering Display

Plantbase topic involved:

fl_duration

The floral display of plants are characteristically either clearly defined, as in the case of species which flower from preformed buds laid down in the previous season, and therefore with a definite beginning and end, e.g Rhododendron, or alternatively as a more or less continuous series of flushes as in certain Rosa hybrids.

The typical length of the latter groups flowering season is much more difficult to assess as it is greatly influenced by both the characteristics ofthe growing season and cultivation inputs. The sporadic often ineffectual floral displays which sometimes occur outside the main flowering season are not reflected in this Plantbase assessment, e.g the autumnal display of Clematis montana.
Flowering display duration is categorised as follows on Plantbase:

very long, greater than or equal to 9 weeks
long, 6-9 weeks
average, 3-6 weeks
short, less than or equal to 3 weeks

c) Duration of Fruiting Display

Plantbase topic involved:

fr_persist

For the purposes of Plantbase fruit display commences when the fruiting structures assume the colour, size and form characteristic of the mature fruit. Fruit display is considered to have finished when the fruits cease to meet these criteria. It is proposed that the latter definition provides a more useful yardstick of the termination of fruiting display than does fruit abscission,as some fruits are retained as decomposing orbs, a condition exemplified by some Malus.

On Plantbase the following categories of fruit persistence are recognised:

very long, greater than or equal to 12 weeks
long, 8-12 weeks
average, 4-8 weeks
short, less than or equal to 4 weeks

Fruit persistence is very strongly influenced by variables such as the incidence of avian and mammalian predation and the severity of the early winter months.

Data for this assessment has been collected over the course of two winters in several of the collections in Table 7.2, in order to try and minimise the influence of these variables.

7.36 Intensity of Display

Plantbase topics involved:

form_intens

s_intens

b_intens

lf_intens_spr

lf_intens_sum

lf_intens_aut

lf_intens_win

lf_intens_av

fl_intens

fr_intens

m_eff

m_eff_av

m_jan

m_feb

m_mar

m_apr

m_may

m_jun

m_jul

m_aug

m_sep

m_oct

m_nov

m_dec

The quantification of quality of plant display, in terms of "contribution to the landscape" has been a major objective of Plantbase. The traditional decorative plant literature treatment of display is frequently confined to recording only the plants most attractive attributes.

The non decorative plant specialist is easily misled by a literature which rarely documents the plants negative display attributes.

In addition to this, by relying solely on adjectival descriptions of display, comparisons of the quality of different species or cultivars are made difficult or impossible. It is with these deficiencies in mind that a means of quantifying display via a system of ratings has been devised for Plantbase.

Within Plantbase display is documented by the following topics:

a) Display derived from overall plant form

b) Display derived from plant stems

c) Display derived from plant bark

d) Display derived from leaf characteristics in Spring

e) Display derived from leaf characteristics in Summer

f) Display derived from leaf characteristics in Autumn

g) Display derived from leaf characteristics in Winter

h) Display derived from flower characteristics

i) Display derived from fruit characteristics

j) Contribution of the whole plant to the landscape in each month of the year, January to December (i.e 12 individual ratings)

k) Mean contribution of the whole plant to the landscape across the year

l) Contribution of whole plant to landscape in January

m) Contribution of whole plant to landscape in February

n) Contribution of whole plant to landscape in March

o) Contribution of whole plant to landscape in April

p) Contribution of whole plant to landscape in May

q) Contribution of whole plant to landscape in June

r) Contribution of whole plant to landscape in July

s) Contribution of whole plant to landscape in August

t) Contribution of whole plant to landscape in September

u) Contribution of whole plant to landscape in October

v) Contribution of whole plant to landscape in November

w) Contribution of whole plant to landscape in December

The monthly effect assessments (topics j - w) represent the integration of all the display assessments for component parts into one rating, to provide an overall picture of plant contribution to the landscape. Assessments of plant contribution to the landscape cannot unfortunately be based on simple, measurable criteria such as size or weight. Instead, parameters such as form, texture, colour and scent have to be employed. In doing so subjectivity is introduced as even within a culture in which aesthetic norms are at least loosely defined, individual perception of beauty or quality varies enormously. (Appleton 1975)

In an attempt to minimise the subjective element, the display contribution of overall plant form, stems, bark, leaves, flowers, and fruit has been evaluated by identifying taxa for each category of display in terms of exceptional, high, average, low, and using these as reference species against which the quality of other taxa can be evaluated.

Reference species for the display topics of Plantbase are listed in Table 7.19.

The aggregate parameter of monthly display is assessed on a 0-9 scale as opposed to the 1-4 scale used to quantify individual display components. This extended range necessitated a more quantified approach, and this has been done by employing a reference scale in conjunction with display correction factors.

A rating for plant display in each month has been arrived at by adding or subtracting the appropriate display correction factors (Table 7.21) to or from the reference scale in Table 7.20.

The evaluation of display contribution or plant quality, recorded on Plantbase is primarily based upon data collected at regular intervals over the life of the project from a selection of the collections identified in Table 7.2

Table 7.19 Derivation of Plantbase Display Values: Reference Species for each Category of Display

Display Topic	Categories of Display			
	Exceptional	High	Average	Low
form_intens	-	Berberis verruculosa	Cornus alba	Hydrangea quercifolia
	-	Cornus controversa	Cotoneaster 'Skogholm'	Malus 'Eleyi'
	-	Cotoneaster 'Gnom'	Prunus sargentii	Rosa 'Queen Elizabeth'
	-	Eucalyptus niphophila	Sorbus aria	Syringa vulgaris
	-	Picea omorika	Viburnum opulus 'Compactum'	Weigelia 'Bristol Ruby'
s_intens	-	Acer palmatum 'Senkaki'	Acer platanoides	Dipelta floribunda
	-	Cornus alba 'Sibirica'	Cornus alba	Forsythia 'Lynwood'

	-	Rubus cockburnianus	Kerria japonica	Hydrangea macrophylla
	-	Salix alba 'Chermesina'	Leycesteria formosa	Rosa 'Peace'
	-	Salix matsudana 'Tortuosa'	Philadelphus 'Sybille'	Weigelia 'Bristol Ruby'
b_intens	-	Acer griseum	Betula pendula	Alnus incana
	-	Betula jacquemontii	Fagus sylvatica	Fraxinus excelsior
	-	Eucalyptus dalrympleana	Pinus sylvestris	Malus hupehensis
	-	Myrtus luma	Prunus avium	Populus nigra
	-	Prunus serrula	Zelkova carpinifolia	Tilia cordata
lf_intens_spr	Acer pseudoplatanus 'Brilliantissimum'	Acer cappadocicum	Acer pseudoplatanus	-
	Clematis armandii	Eucalytus gunnii	Berberis rubrostilla	-
	Pieris forrestii 'Wakehurst'	Fagus sylvatica	Ceanothus 'Cascade'	-

	Rhododendron 'Bow Bells'	Salix 'Chrysocoma'	Rosa 'Canary Bird'	_
	Sorbus aria 'Lutescens'	Salix lanata	Sorbus aucuparia	_
lf_intens_sum	Alnus glutinosa 'Imperialis'	Liriodendron tulipfera	Escallonia 'Appleblossom'	Acer pseudoplatanus 'Brilliantissimum'
	Aralia elata 'Aureovariegata'	Prunus lusitanica	Magnolia stellata	Laburnum 'Vossii'
	Cotinus cogygria 'Royal Purple'	Rhus typhina	Prunus 'Kanzan'	Malus 'Profusion'
	Danae racemosa	Sorbus sargentiana	Pyracantha 'Orange	Philadelphus 'Virginal'
	Viburnum rhytidophyllum	Viburnum davidii	Rosa 'Nevada'	Weigelia 'Bristol Ruby'
lf_intens_aut	Acer palmatum 'Ozakazuki'	Acer platanoides	Cornus alba	Ceanothus 'Gloire de Versaille'
	Berberis thunbergii	Hamamelis 'Hiltingbury'	Forsythia 'Lynwood'	Clematis x jackmannii
	Liriodendron tulipfera	Parrotia persica	Prunus 'Ukon'	Ficus carica

	Parthenocissus tricuspidata	Rhododendron luteum	Robinia pseudoacacia	Hydrangea macrophylla
	Sorbus 'Embley'	Sorbus sargentiana	Sorbus aria	Sambucus nigra
lf_intens_win	Danae racemosa	Cotoneaster congestus	Cupressocyparis leylandii	Carpenteria californica
	Hedera colchica 'Paddys Pride'	Fatsia japonica	Cytisus x kewensis	Cotoneaster 'Cornubia'
	Ilex 'Camellifolia'	Magnolia grandiflora	Osmanthus delavayii	Embothrium coccineum
	Lomatia ferugineum	Prunus lusitanica	Prunus laurocerasus	Garrya elliptica
	Mahonia lomariifolia	Quercus ilex	Pyracantha 'Orange Glow'	Viburnum rhytidophyllum
lf_intens_av	-	-	-	-
fl_intens[a]	Ceanothus 'Cascade'	Amelanchier canadensis	Berberis wilsonae	Cotoneaster 'Skogholm'
	Laburnum 'Vossii'	Berberis darwinii	Fuchsia magellanica	Euonymus alatus
	Magnolia sargentiana robusta	Elaeagnus x ebbingei	Potentilla fruticosa	Ilex aquifolium

	Rhododendron albrechtii	Mahonia japonica	Salix caprea	Populus nigra
	Viburnum tomentosum 'Mariesii'	Rosa rugosa 'Frau Dagmar Hastrup'	Sorbus aucuparia	Quercus robur
fr_intens	Celastrus orbiculatus	Cotoneaster horizontalis	Berberis thunbergii	Alnus glutinosa
	Euonymus 'Red Cascade	Hippophae rhamnoides	Crataegus oxycantha	Betula pendula
	Malus 'Robusta'	Ilex aquifolium	Mahonia aquifolium	Camellia japonica
	Pyracantha atlantoides	Malus 'Golden Hornet'	Malus floribunda	Koelreuteria paniculata
	Viburnum opulus 'Notcutts Variety'	Sorbus hupehensis	Viburnum davidii	Syringa vulgaris

a = assessment based on visual and olfactory characteristics

Table 7.20 <u>Reference Scale for Assessing Overall Monthly Contribution to the Landscape</u>

9 ----------- maximum display possible

8

7

6

5 ----------- display of average plant when in leaf

4

3 ----------- display of average deciduous woody plants when dormant

2

1

0 ----------- minimum display possible e.g herbaceous plants in winter

Table 7.21 Assessment of Plants Overall Monthly Contribution to the Landscape: Display Correction Ratings and Reference Species

Components of overall display	Display Correction Ratings: Minimum display -2	-1	0	1	2	Maximum display 3
plant form	Rosa 'Peace'	Syringa vulgaris	Prunus sargentiana	Cornus kousa chinensis	Cotoneaster horizontalis	Picea breweriana
plant stems	-	-	Hamamelis mollis	Philadelphus 'Sybille'	Cornus stolonifera 'Flaviramea'	Cornus alba 'Sibirica'
plant bark	-	-	Tilia cordata	Fagus sylvatica	Eucalyptus niphophila	Prunus serrula
plant leaves in spring	-	-	Sambucus nigra	Salix 'Chrysocoma'	Sorbus 'Mitchellii'	Pieris forrestii 'Wakehurst'
plant leaves in summer	-	Laburnum 'Vossii'	Magnolia stellata	Cornus kousa	Viburnum davidii	Aralia elata

plant leaves in autumn	-	Clematis x jackmannii	Sorbus aria	Rosa rugosa	Sorbus sargentiana	Acer palmatum 'Ozakazuki'
plant leaves in winter	-	Carpenteria californica	Berberis stenophylla	Ceanothus 'Cascade'	Mahonia lomariifolia	Ilex 'Camellifolia'
plant flowers (visual)	-	-	Ilex aquifolium	Sorbus aucuparia	Berberis darwinii	Magnolia sargentiana robusta
plant flowers (scent)	-	-	Hypericum 'Hidcote'	Rosa 'Penelope'	Chimonanthus praecox	-
plant fruit	Malus 'Golden Hornet'[1]	Chaenomeles 'Crimson and Gold'	Betula pendula	Berberis thunbergii	Cotoneaster horizontalis	Pyracantha atlantoides

1 = when decomposing on the tree

7.37 Leaf Persistence

Plantbase topic involved:

lf_persist

On Plantbase the following categories of leaf persistence are recognised:

evergreen
semi evergreen - tardily deciduous
deciduous

7.38 Plant Life Cycle

Plantbase topic involved:

life_cyc

On Plantbase the following categories of plant life cycle are recognised:

annual
biennial
perennial woody shrub
perennial woody tree
perennial woody climber
perennial semi-woody
perennial non-woody (bulb or herbaceous)
perennial non-woody climber
perennial non-woody aquatic

On Plantbase trees are defined as woody plants which naturally develop a clear stem of 1 metre or greater.

7.39 Indigenous or Naturalised

Plantbase topic involved:

indig_nat

Indigenous or naturalised species have long been the preferred choice for rural landscapes in Britain, whilst introduced or exotic species have dominated urban landscapes. During the past decade events overseas and particularly in Holland, have led to a questioning of the validity of using introduced species even within urban landscapes (Laurie 1979). The native plant movement is based at least in part in the desire to halt the divergence of urban man from nature, and to recreate the vegetational framework upon which to re-establish food chains long interupted in the built environment.

On Plantbase this topic indicates the generally greater potential of indigenous, over introduced species, to satisfactorily complete their life cycle in Britain, and produce a self sustaining community.

For most woody species, the production of viable seed is an obvious prerequisite for this to occur. This is largely determined by the prevailing solar radiation and air temperature regime. In the upland and Northern regions of England and Wales, species native to Southern England but which are essentially continental European in character such as <u>Acer campestre</u>, <u>Euonymus europaeus</u>, <u>Tilia cordata</u> grow satisfactorily but rarely produce viable seed. (Salisbury 1939). These responses are brought to the users attention in User Limitations.

Even where the overall insolation temperature regime is satisfactory, ultimately successful seedling regeneration frequently rests upon localised factors such as competing vegetation and the level of avian and small mammal predation. (Peterken 1981).

Although in most cases indigenous species may be at an advantage over aliens in terms of a closer fit with the planting site environment, this does not mean they are not equally sensitive to environmental stresses such as those generated by weed competition and soil compaction. From a landscape point of view, indigenous does not by itself guarantee success.

7.40 Plant Taxonomy

Plantbase topic involved:

taxon

On Plantbase a subject may be recorded as belonging to one of the following taxonomic groups:

conifers and other gymnosperms

monocotyledons

dicotyledons

ferns and lower plants

8. Discussion

In contrast to much of contemporary biological research the Hortbase project has by its very nature, necessitated an extremely broad research effort. To summarise and discuss the work it is necessary to look at the objectives of the project, and in particular focus on a number of specific objectives. These are as follows:

a) The end product of the research should be in a form that enables it to be available to a large number of professional users

b) The system must be able to provide the user with information in a format that facilitates prompt decision making on plant usage

c) To investigate means by which information on decorative plants could be most satisfactorily quantified for inclusion in a database format

d) To provide information that was in step with contemporary thought on plant usage and cultivation practice in the landscape of institutions and public open space

e) The information system should reflect the richness of the British cultivated flora

f) To record and store some of the knowledge of decorative plants accumulated by plantspersons over their lifetimes so that this would not be lost upon their death

One might commence by asking to what extent have these objectives been fulfilled.

At the commencement of the project, relational databases were synonymous with the mainframe computer, and, due to the costs associated with the latter, access was restricted largely to governmental and institutional bodies such as the universities and in the commercial world, medium to large companies. The bulk of database usage was essentially an "in house" operation, although in some cases access was available to those outside the parent organisation via a rental charge.

Hence in 1979 the means by which the product of the research project could be popularised was far from clear. The most realistic option seemed to be to develop a database model that a Database house could be persuaded to maintain on a mainframe, and which users could access via rented telephone line terminals. Given the size of the market, it was anticipated that the likely cost of this service would be high, and would inevitably exclude all users other than those associated with the institutions and the larger practices involved in landscape. The economic attraction of such an arrangement to the mainframe operator appeared suspect, however despite these nagging worries it was decided that a start had to be made somewhere.

As a result, when the Honeywell Multics (a sophisticated mainframe computer system) came on line at the South Western Universities Computer Centre in the same year it appeared to be the ideal vehicle for the research, a view supported by computer centre staff. The attraction of the Multics system was the wide range of database creation and management software that it supported, plus the back up of specialist advisory staff.

Over the next two years it became increasingly obvious that the rapid technological advances that were being made in the development of microcomputers, would ultimately provide the means by which access to small to medium databases would be facilitated. By this time it was however too late to change direction, and the decision was taken to continue working with the Multics system.

In practice, this was the only realistic option as at the time no microcomputer hardware or software was available to the author that would adequately handle databases of the envisaged dimensions, indeed it is only relatively recently that these have become available. A database management package such as dBase II requires a minimum of 48K of RAM memory to contain just the database programme (Wood 1982).

It is the declining cost of and technical developments in information storage systems such as the hard or Winchester disk that has really allowed the microcomputer to become a serious contender in database use. Hard disks not only facilitate enormous information storage capacity (e.g 5-40 megabytes compared with approximately 250 to 930 kilobytes for double density floppy disks), but also dramatically reduce the time taken to search a file when retrieving information compared with floppy disk storage. In its current prototype form of 200 plant records the storage requirements of Hortbase are in the region of 100 k. At a projected size of 3,500 plant records this would increase to approximately 2 megabytes (2 million characters).

Because of its mainframe requirements, Hortbase is currently available to in house users only, and this is inevitably a serious failing.

Very closely associated with user accessibility is the ease with which the layman user can operate the system to obtain information. Computer ease of use is commonly referred to as "user friendliness", and one of the characteristics of contemporary microcomputer software is that manufacturers have striven to make it as "friendly" as possible. Comparisons between the user friendliness of Honeywell Multics and current micro packages are perhaps unfair, as they are orientated towards satisfying the needs of different markets, with the former being a product of the technology of the mid 1970's.

Although the Multics system is not particularly user friendly with regard to the construction, population and maintenance of databases, it is a relatively easy system with which to retrieve information. The procedure and syntax of information retrieval is documented in Hortbases User Handbook. (See Appendices)

From a users point of view, the main deficiencies in the Multics software currently being used to retrieve information from Hortbase is that it does not prompt the user, via a screen menu, but rather leaves him or her to make the next move. This format may be advantageous to the experienced user, as it may allow greater flexibility when retrieving information, as the user is not fettered by a limited range of options as is sometimes the case with some microcomputer database software. It does however increase the effort required to retrieve information, and as such disadvantages the inexperienced user.

In addition to this the software of the Multics system is far less tolerant of imprecision in retrieval requests (e.g spelling mistakes) than are some micro computer database packages.

Ultimately the main driving force behind the development of Hortbase was the need to produce a system that could supply a professional with the information that he or she needed to make a decision. It was hoped that this might lead to better plant selection and management, and ultimately an improved standard of landscape.

Whether or not potential Hortbase users will view a system such as Hortbase as an improvement on traditional information sources will depend very much upon the extent to which they recognise the deficiencies of existing information sources. On a superficial level presumably all would recognise the advantages of the computers great speed of information retrieval, even when searching on multiple criteria, compared with searching the literature.

Fewer people may recognise the database as an aid to imaginative design. The computer can fulfill the latter use because firstly it searchs on the total set of data rather than just the taxa that are recalled from memory at a particular time. Secondly it will select plants without bias; the lists frequently include subjects that a person might well have categorised as unsuitable. Logical impartiality is indeed a most valuable quality when assembling a short list of suitable plants. The author contends that systems such as Hortbase have qualities far beyond that of merely being a faster way of retrieving information.

Many of the potential users of Hortbase do not have a background in the biological sciences. Like the amateur gardener they are often relatively ignorant of the factors which determine the performance of plants, and that these are often based on relatively simple and fairly well understood phenomena. Consequently they may be uncomfortable with the fundamental and rather dry style of Hortbase.

As an example, the Hortbase topic of plant response to physical soil conditions is essentially concerned with the effect of varying soil oxygen levels and bulk densities on the root systems of different species, these being the most significant physical factors determining the degree of soil hostility.

Some observers have been suprised or even concerned that such an approach should, or indeed can be applied as they have been educated to think in terms of symptoms rather than causes, i.e in terms of textural classes or geological origins.

A common misconception with databases is that they are a substitute for human judgement. The information that Hortbase records is essentially simple in format and does not for example, attempt to paralell the thought processes of the designer, e.g synthesize a solution to a number of competing design requirements.

Although it has not been attempted it would however be relatively easy to proceed to the next level of information retrieval and construct a database which would at least in part, be able to do this.

For example, given one plant species, most experienced designers would intuitively be able to identify other species (in terms of colour, habit, form, texture, size) which, when associated with the first species create a predictable visual effect. These effects would be based upon human perception of concepts such as harmony, contrast, unity, rhythm, and intangibles such as style and historical associations.

Although it would take a great deal of time to identify and quantify the large number of variables that determine these relationships for any species, a database system which addresses itself to this level of information is possible. The justifiable criticism of such a system would seem to be considerable. Apart from the difficulties of design architecture a major problem of such a database would be that the information it contained would represent the views of only a few designers (i.e the creators) at a specific time, and unless constantly updated would be divorced from the influences that promote an evolution of design thought.

This type of database might prove to be a useful tool by increasing the competence of inexperienced designers although it would be unlikely to produce works of genius.

To produce this type of database requires an extremely large number of interactions to be investigated, and to the authors knowledge, within the field of horticulture and landscape design no such system currently exists.

Unlike a scientific text book, a database such as Hortbase is orientated towards what may be considered to be a lay audience, and must therefore be able to convey information in a format that can be acted upon without further extrapolation. This requirement imposes severe restictions on database format and ways in which information is stored.

The information contained within the database represents only the peak of a very broad pyramid of information. Much of the authors time has been spent in quantifying and reducing the pyramid so that the user may be confronted with a concise range of options typified by the division of floral intensity of display into very high, high, average, and low. On the actual database, in common with several other fields these ratings have been reduced to the numerals 4, 3, 2, 1. This practice has advantages and disadvantages as previously discussed in Section 5, but was necessary during the development of Hortbase in order to minimise consumption of the projects restricted allowance of computer space within the Multics network.

The need to reduce often complex interactions to this final format has resulted in several problems. The most important of these is that it has been necessary to over simplify and generalise. This has proved to be a particularly serious problem in deriving values for the microclimate adjustment factors of Climatebase. Here the author was convinced of the need to build in representative values but was hampered by the paucity of recorded information. Accordingly in some cases the adjustment figures in Climatebase are based upon very limited data and are little more than informed estimates. Despite this the author believes their presence far out weighs the disadvantages they pose as estimates.

The essence of the problem is that it is unwise to construct a database that depends too heavily on the users ability to analyse. Take for example, the environment of the planting site. Here the topic of plant response to soil moisture deficits has been treated very simplistically within Hortbase, and the inevitable complications and error introduced by the varying available water content of different soils has been conveniently omitted. If the author could have been sure that Hortbase users would be capable of reliably assessing the AWC of urban soils this factor would have been incorporated into Hortbase. Given the heterogeneity of urban soils and the background of the envisaged users it was decided that this kind of feed back could not be relied upon.

Some quantification problems have arisen only as the author investigated the causative phenomena. This was the case with the effect of exposure upon winter minima and ultimately plant hardiness. Within the horticultural literature shelter from wind is generally assumed to have a moderating influence upon the development of low temperatures and therefore frost injury (Royal Horticultural Society 1948 a,b, 1963, 1964). The following microclimatic factors were considered for incorporation into Climatebase.

a) Effect of woodland upon winter minima

b) Effect of shelter upon winter minima

c) Effect of exposure upon winter minima

As these topics were researched it became clear that they could not be included in Climatebase as depending upon the prevailing weather, all 3 can be responsible for both an increase or decrease in the minima experienced.

Woodland is often considered to be a favourable microclimate for alleviating winter cold, but because the leafless canopy of deciduous woodland reduces wind speed without appreciably reducing long wave radiation losses, this results in localised thermal stratification and a greater risk of severe frost. (Caborn 1957) This situation only occurs when the wind speed drops below a critical value, and during conditions of cyclonic weather or advective frost deciduous woodland is likely to be warmer. These phenomena have been demonstrated for Beech Forest in Ohio (Christy 1952).

As for shelter and exposure, under cyclonic (windy and wet) or at the other extreme conditions of advective frost, sheltered planting sites will experience less cold then exposed sites. However on radiation nights the reduced wind velocity will result in localised thermal stratification which in turn will often result in sheltered locations experiencing the lowest temperatures. This must be balanced against the damaging effect of dehydration of susceptible evergreens during the winter in exposed sites. As a result of this no attempt has been made to link the degree of shelter or exposure with the winter hardiness zones of Climatebase. Instead, evergreen species that are particularly susceptible to this form of damage and must be located accordingly, are listed as such in User Limitations.

The content of Hortbase attempts to reflect the objective that the information system should be in step with contemporary thought. Amongst others, topics such as tolerance of stooling and coppicing, residual herbicides, sub optimal or degraded soils, vegetative and reproductive performance in localised shade are all issues of current interest which are inadequately documented in the literature.

The newness of areas such as plant tolerance to herbicides and degraded soils means that much of the related knowledge is held either by practitioners or scattered throughout the literature. It has not yet been published in a concise or readily available form. This often gives the impression to non specialists that far less is known about a topic than is actually the case. Consequently, the author has attempted to locate and bring together these sources of information via Hortbase.

Britain possesses a unique heritage in the richness of decorative plants to be found in her landscapes and gardens. Within the former, landscape architects are now perhaps the most influential group of plant selectors, although very few could be considered to be knowledgeable or supportive of the wealth of plant material available to them. The publishing of documents such as the JCLI plant list, (JCLI 1978) however well intentioned will doubtless serve to further define the extent to which this groups plantsmanship is developed.

In addition, the increase in the usage of indigenous species in locations traditionally dominated by non-native species, will, independent of the soundness of this policy, further erode the desire to acquire an intimate knowledge of exotic species.

Ominously these trends are paralelled by a rationalisation on economic grounds of the range of decorative plnats offered by many nurseries, and increasing concern is being expressed by groups (Brickell 1979) who feel part of their heritage is being lost. For many producers, rationalisation is an economic inevitability, but it is hoped that the impact of this will be cushioned by the emergence of growers who will specialise in a particular group of plants. This has already happened for example, in the case of the genus Clematis, and there are now at least 3 specialist producers who between them can offer most of the cultivars and species that have been recorded in cultivation.

Although many of the taxa over which most concern has been expressed are not important in terms of the broader landscape, as a plantsman, the author saw Hortbase as a means by which information on unfamiliar species with landscape potential could be made available to non-plantsmen, thereby creating a demand for currently unfamiliar but worthy plants to which the nursery stock industry might respond. This is not a view shared by all nurserymen, some of whom it would appear wish to be in a position by which they alone determine what species and cultivars will be available. This may be beneficial to the economic interests of the nurseryman, but will surely have an undesirable impact upon the development of the British urban landscape. An "expert" independent information system such as Hortbase may be seen by some nurserymen as a threat which will interfere with their rationalisation plans and weaken them in their role as information providers to customers such as landscape architects. In an era when many industries are becoming truly market as opposed to sales orientated the author believes it is essential that independent information is readily available and that the nursery industry should be prepared to adjust to meet new demands. The alternative is stagnation in the range of plant materials in everyday use. This has already tended to happen in the USA.

The producers suspicions of information systems such as Hortbase appear to stem from the fear that they will generate demand that they cannot, at least in the short term, meet. In principle therefore a partial solution to the problem would be to link the nurserymans stock availability status with Hortbase or a comparable system. Such a development would be of potentially enormous benefit to the landscape industries, but until the majority of nurseries have adopted a system of computerised stock control, such a move would be highly unequitable as it would favour only the largest producers, and disadvantage the smaller specialist producer.

Approximately 3,500 species and cultivars were initially identified as possessing sufficient aesthetic quality and environmental tolerance to be included within Hortbase. By the end of the project 200 of these had been incorporated. The author estimates that an input of at least 2000 man hours would be required in order to complete this task.

Associated with this objective remains the desire to make Hortbase a repository for information collected during interviews with plantsmen whose wealth of observations would otherwise ultimately be lost through death. Time did not permit this during this study, but such work would undoubtably be of great value.

As a result of its limited accessibility and the relatively small number of plants that it contains, Hortbaseis best considered as an operationalprototype. It is unfortunate that the pace of microcomputer technology has come to mean that small to medium sized databases such as Hortbase, when developed in conjunction with a mainframe computer, are something of a white elephant. This label applies to the vehicle and not the format or content of the database. It is unlikely that any of the plant selection databases that are currently under development or will be developed in the immediate future will be so rigorous in the attention they pay to quantifying and recording plant characteristics.

Whilst such systems will inevitably arrive at the same range of topics as included in Hortbase few of the systems aimed at the non scientist are likely to attempt to document plant response to climate, and most importantly plant response to the climate of a specific planting site. Climatebase is, in the authors opinion the most valuable component of Hortbase, and it is hoped it will encourage others to research and attempt to further quantify amenity plant performance in response to climatic and other environmental factors.

As for the future, it is to be hoped that now that much of the ground work has been completed and house rules for information quantification established, it will be possible for someone to take over where the author has left off. The two most immediate tasks are completion of the Plantbase database, and transference of the database to a microcomputer. The latter would require the restructuring of Hortbases current format, for example, Plantbase would perhaps be best split into several smaller relations. This does not present any insurmountable difficulties especially if a competent typist was available. In its current form, when expanded to 3,500 plants Hortbase would demand a data storage capacity of approximately 2 megabytes. As previously mentioned, as a result of file space constraints, Hortbase was by necessity designed to be as space efficient as possible, and information is recorded primarily as numeric or character codes. This approach is not ideal for all topics and would need to be reviewed prior to restructuring.

It is reasonable to assume that a more user friendly Hortbase restructured to a microcomputer format would have a data storage requirement of 5 to 10 megabytes. Logically this size of database would necessitate the use of hard or Winchester disks for storage. Unfortunately these are considerably more expensive than floppy disk systems but have greatly enhanced performance.

As for the software necessary to construct, manage and retrieve information from the database, there are several options.

The first requires a database programme to be specially written or an existing one modified to handle Hortbase. In principle this is perhaps the most satisfactory option as it would allow for an "all in" Hortbase package consisting of both data set and programme. Arbordata (Anon 1984), an information system on trees and shrubs is a good example of this approach.

The second option is also potentially satisfactory,and involves utilising one of a number of popular, existing relational database management packages such as dBase II (Ashton Tate 1981) to construct and populate the Hortbase datamodels. Data would be marketed to users who owned or were prepared to purchase one of these general purpose database packages as a series of appropriately formatted floppy discs. A database of 5 megabytes would necessitate approximately 20 double density 5.25 inch floppy data discs. On receipt of the discs the purchaser would electronically copy this data from the floppies onto his systems hard disc allowing all the data to be accessed as required.

The hardware required to run a database of this size would comprise a microcomputer with a minimum of 64k RAM, a VDU screen and printer, a floppy disc drive and a 10 megabyte Winchester disc drive. As many potential users would likely possess a suitable microcomputer, VDU and printer, the main expenditure might well be a figure of approximately £ 1200-2000 for an appropriate Winchester drive. The author believes that Hortbase has commercial potential and hopes that the project can be developed along the paths outlined to produce a marketable product.

The Hortbase project has not resulted in an information system containing data on 3,500 taxa which is now available to landscape practitioners. Given the nature of the project and the resources available, the fulfilment of these objectives has proved to be incompatible with the investigation and quantification of the component topics. This is regetable, but is balanced by the fact that the author has been able to look critically at information areas that have generally been passed over by Amenity Horticulture and related disciplines.

What the project has produced is a model that demonstrates the value of computer information retrieval systems to the landscape professions and which provides a base camp for those who follow.

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Appendix I

Calculation of Influence of Microclimatic Factors

Data derived from Met. Office (1976)

1 Winter Cold

1.1 Valley Bottoms

Houghall:

	Alt	Ref Area	DD	Nov-Jan Mean Month Min °c
Houghall	37	5	-	-8.1
Durham	102	5	166.5	-5.7

Estimated DD deviation of Houghall from Durham =

(166.5 x 1.42) - 166.5 = 69.9 = 1.7 Winter cold zones

Usk:

	Alt	Ref Area	DD	Nov-Jan Mean Month Min °c
Usk	21	25s	-	-6.1
Cheltenham	65	30	95.3	-4.7
Long Ashton	51	30	95.3	-4.5

Estimated DD deviation of Usk from Cheltenham =

(95.3 x 1.30) - 95.3 = 28.6 = 0.7 Winter cold zones

Estimated DD deviation of Usk from Long Ashton =

(95.3 x 1.35) - 95.3 = 33.3 = 0.8 Winter cold zones

Rickmansworth Frost Hollow:

	Alt	Ref Area	DD	Nov-Jan Mean Month Min °c
Rickmansworth	* 55	33w	-	-11.6
Rothamsted	128	33w	141.6	-5.5

Estimated DD deviation of Rickmansworth from Rothamsted=

(141.6 x 2.11) - 141.6 = 157.2 = 3.9 Winter cold zones

* = data for Braemar

1.2 Urban Centres

Hampstead:

	Alt	Ref Area	DD	Nov-Jan Mean Month Min °c
Hampstead	137	L	-	-3.8
Wisley	35	32	106.3	-5.3
St. Albans	83	33w	141.6	-5.9

Estimated DD deviation of Hampstead from Wisley =

106.3 - (106.3 x 0.71) = 30.8 = 0.8 Winter cold zones

Estimated DD deviation of Hampstead from St. Albans =

141.6 - (141.6 x 0.64) = 51.0 = 1.3 Winter cold zones

Kensington:

	Alt	Ref Area	DD	Nov-Jan Mean Month Min °c
Kensington	25	L	-	-2.9
Wisley	35	32	106.3	-5.3
St. Albans	83	33w	141.6	-5.9

Estimated DD deviation of Kensington from Wisley =

106.3 - (106.3 x 0.55) = 47.8 = 1.2 Winter cold zones

Estimated DD deviation of Kensington from St. Albans =

141.6 - (141.6 x 0.49) = 72.2 = 1.8 Winter cold zones

Kew:

	Alt	Ref Area	DD	Nov-Jan Mean Month Min °c
Kew	6	L	-	-3.2
Wisley	35	32	106.3	-5.3
St. Albans	83	33w	141.6	-5.9

Estimated DD deviation of Kew from Wisley =

106.3 - (106.3 x 0.60) = 42.5 = 1.1 Winter cold zones

Estimated DD deviation of Kew from St. Albans =

141.6 - (141.6 x 0.54) = 65.1 = 1.6 Winter cold zones

Regents Park:

	Alt	Ref Area	DD	Nov-Jan Mean Month Min °c
Regents Park	39	L	-	-3.1
Wisley	35	32	106.3	-5.3
St. Albans	83	33w	141.6	-5.9

Estimated DD deviation of Regents Park from Wisley =

106.3 - (106.3 x 0.58) = 44.7 = 1.1 Winter cold zones

Estimated DD deviation of Regents Park from St.Albans =

141.6 - (141.6 x 0.52) = 69.0 = 1.7 Winter cold zones

Birmingham Edgebaston:

	Alt	Ref Area	DD	Nov-Jan Mean Month Min °c
Birmingham Edgebaston	163	20	-	-3.4
Oaken	125	19	159.0	-5.7

Estimated DD deviation of Birmingham from Oaken =

159.0 - (159.0 x 0.60) = 63.6 = 1.6 Winter cold zones

Nottingham:

	Alt	Ref Area	DD	Nov-Jan Mean Month Min °c
Nottingham	59	16	-	-4.0
Sutton Bonnington	48	16	147.3	-6.1

Estimated DD deviation of Nottingham from Suttom Bonnington =

147.3 - (147.3 x 0.65) = 51.6 = 1.3 Winter cold zones

Manchester:

	Alt	Ref Area	DD	Nov-Jan Mean Month min °c
Whitworth Park	40	8	-	-3.3
Barton Airfield	20	8	127.0	-5.6

Estimated DD deviation of Whitworth Park from Barton Airfield =

127.0 - (127.0 x 0.59) = 52.1 = 1.3 Winter cold zones

1.3 <u>Coastal Proximity</u>

Tynemouth:

	Alt	Ref Area	DD	Nov-Jan Mean Month Min °c
Tynemouth	29	1s	-	-2.6
Durham	102	5	166.5	-5.7
Ushaw	181	5	198.0	-4.4
Chopelwood	136	1s	174.5	-5.3
Cockle Park	99	1s	174.5	-4.6
Acklington	42	1s	143.0	-5.2

Estimated DD deviation of Tynemouth from Durham =

166.5 - (166.5 x 0.46) = 89.9 = 2.2 Winter cold zones

Estimated DD deviation of Tynemouth from Ushaw =

198.0 - (198.0 x 0.59) = 81.2 = 2.0 Winter cold zones

Estimated DD deviation of Tynemouth from Chopelwood =

174.5 - (174.5 x 0.49) = 89.0 = 2.2 Winter cold zones

Estimated DD deviation of Tynemouth from Cockle Park =

174.5 - (174.5 x 0.56) = 76.8 = 1.9 Winter cold zones

Estimated DD deviation of Tynemouth from Acklington =

143.0 - (143.0 x 0.50) = 71.5 = 1.8 Winter cold zones

Redcar:

	Alt	Ref Area	DD	Nov-Jan Mean Month Min °c
Redcar	8	5	-	-3.6
Durham	102	1s	166.5	-5.7
Ushaw	181	5	198.0	-4.4
Chopelwood	136	5	174.5	-5.3
Cockle Park	99	1s	174.5	-4.6
Acklington	42	1s	143.0	-5.2

Estimated DD deviation of Redcar from Durham =

166.5 - (166.5 x 0.63) = 61.6 = 1.5 Winter cold zones

Estimated DD deviation of Redcar from Ushaw =

198.0 - (198.0 x 0.82) = 35.6 = 0.9 Winter cold zones

Estimated DD deviation of Redcar from Chopelwood =

174.5 - (174.5 x 0.68) = 55.8 = 1.4 Winter cold zones

Estimated DD deviation of Redcar from Cockle Park =

174.5 - (174.5 x 0.78) = 38.4 = 1.0 Winter cold zones

Estimated DD deviation of Redcar from Acklington =

143.0 - (143.0 x 0.69) = 44.3 = 1.1 Winter cold zones

Skegness:

	Alt	Ref Area	DD	Nov-Jan Mean Month Min °c
Skegness	5	17e	-	-3.5
Cranwell	62	17w	148.8	-4.9
Lincoln	7	17w	148.8	-6.7

Estimated DD deviation of Skegness from Cranwell =

148.8 - (148.8 x 0.71) = 43.2 = 1.0 Winter cold zones

Estimated DD deviation of Skegness from Lincoln =

148.8 - (148.8 x 0.52) = 71.4 = 1.8 Winter cold zones

Clacton:

	Alt	Ref Area	DD	Nov-Jan Mean Month Min °c
Clacton	16	33e	-	-2.9
Earles Colne	49	33e	123.9	-4.0
Cambridge B.G	12	28	140.0	-5.8
Maldon	4	33e	123.9	-4.8
Writtle	32	33e	123.9	-5.7

Estimated DD deviation of Clacton from Earles Colne =

123.9 - (123.9 x 0.72) = 34.7 = 0.9 Winter cold zones

Estimated DD deviation of Clacton from Cambridge B.G =

140.0 - (140.0 x 0.50) = 70.0 = 1.7 Winter cold zones

Estimated DD deviation of Clacton from Maldon =

123.9 - (123.9 x 0.60) = 49.6 = 1.2 Winter cold zones

Estimated DD deviation of Clacton from Writtle =

123.9 - (123.9 x 0.50) = 62.0 = 1.5 Winter cold zones

Dover:

	Alt	Ref Area	DD	Nov-Jan Mean Month Min °c
Dover	6	39e	-	-2.4
Wye	56	39w	111.8	-5.2
Bodiam	22	38n	112.2	-6.0

Estimated DD deviation of Dover from Wye =

111.7 - (111.7 x 0.46) = 60.3 = 1.5 Winter cold zones

Estimated DD deviation of Dover from Bodiam =

112.2 - (112.2 x 0.40) = 67.3 = 1.7 Winter cold zones

Bexhill:

	Alt	Ref Area	DD	Nov-Jan Mean Month Min °c
Bexhill	4	38n	-	-3.1
Wye	56	39w	111.7	-5.2

Estimated DD deviation of Bexhill from Wye =

111.7 - (111.7 x 0.60) = 41.1 = 1.0 Winter cold zones

Bournemouth:

	Alt	Ref Area	DD	Nov-Jan Mean Month Min °c
Bournemouth	40	46	-	-3.8
Shaftsbury	207	45e	121.5	-4.3
Porton	111	36	120.7	-6.1

Estimated DD deviation of Bournemouth from Shaftsbury =

121.5 - (121.5 x 0.88) = 14.6 = 0.4 Winter cold zones

Estimated DD deviation of Bournemouth from Porton =

120.7 - (120.7 x 0.62) = 45.9 = 1.1 Winter cold zones

Sidmouth:

	Alt	Ref Area	DD	Nov-Jan Mean Month Min °c
Sidmouth	10	45w	-	-2.7
Exeter Airport	32	45w	53.2	-4.6

Estimated DD deviation of Sidmouth from Exeter Airport =

53.2 - (53.2 x 0.59) = 21.9 = 0.5 Winter cold zones

Weston S Mare:

	Alt	Ref Area	DD	Nov-Jan Mean Month Min °c
Weston S Mare	9	30	-	-3.3
Cannington	23	35	70.8	-3.9
Long Ashton	51	30	95.3	-4.5

Estimated DD deviation of Weston S Mare from Cannington

70.8 - (70.8 x 0.85) = 10.6 = 0.3 Winter cold zones

Estimated DD deviation of Weston S Mare from Long Ashton

95.3 - (95.3 x 0.73) = 26.1 = 0.6 Winter cold zones

Prestatyn:

	Alt	Ref Area	DD	Nov-Jan Mean Month Min °c
Prestatyn	4	14	-	-3.3
Hawarden Bridge	5	14	118.5	-5.0
Wrexham	58	14	118.5	-5.0

Estimated DD deviation of Prestatyn from Hawarden Bridge

118.5 - (118.5 x 0.66) = 40.3 = 1.0 Winter cold zones

Estimated DD deviation of Prestatyn from Wrexham =

118.5 - (118.5 x 0.66) = 40.3 = 1.0 Winter cold zones

Morecombe:

	Alt	Ref Area	DD	Nov-Jan Mean Month Min °c
Morecombe	7	8	-	-3.4
Stoneyhurst	115	8	158.5	-4.7
Nelson	165	8	190.0	-5.6
Ambleside	46	6	127.5	-6.5

Estimated DD deviation of Morecombe from Stoneyhurst =

158.5 - (158.5 x 0.72) = 44.4 = 1.1 Winter cold zones

Estimated DD deviation of Morecombe from Nelson =

190.0 - (190.0 x 0.60) = 76.0 = 1.9 Winter cold zones

Estimated DD deviation of Morecombe from Ambleside =

127.5 - (127.5 x 0.52) = 61.2 = 1.5 Winter cold zones

1.4 Thermal Belts

Malvern:

	Alt	Ref Area	DD	Nov-Jan Mean Month Min °c
Malvern	114	25n	-	-3.0
Perdiswell	28	25n	113.6	-5.0

Estimated DD deviation of Malvern from Perdiswell =

113.6 - (113.6 x 0.60) = 45.4 = 1.1 Winter cold zones

Sheffield:

	Alt	Ref Area	DD	Nov-Jan Mean Month Min °c
Sheffield	131	10	-	-3.2
Bradford	134	11	169.3	-4.7
Pontefract	78	12	185.9	-4.4
Belper	60	16	147.3	-5.6
Huddersfield	99	11	169.3	-5.5

Estimated DD deviation of Sheffield from Bradford =

169.3 - (169.3 x 0.68) = 54.2 = 1.3 Winter cold zones

Estimated DD deviation of Sheffield from Pontefract =

185.9 - (185.9 x 0.73) = 50.2 = 1.2 Winter cold zones

Estimated DD deviation of Sheffield from Belper =

147.3 - (147.3 x 0.57) = 63.3 = 1.6 Winter cold zones

Estimated DD deviation of Sheffield from Huddersfield =

169.3 - (169.3 x 0.58) = 71.7 = 1.8 Winter cold zones

2 Summer Warmth

2.1 Coastal Proximity

Tynemouth:

	Alt	Ref Area	DD	May-Oct Mean Month Max °c
Tynemouth	29	1s	-	21.3
Durham	102	5	567.6	22.8
Ushaw	181	5	507.6	22.2
Chopelwood	136	1s	477.8	22.8
Cockle Park	99	1s	477.8	23.1
Acklington	42	1s	537.8	21.4
Houghall	37	5	627.6	23.2

Estimated DD deviation of Tynemouth from Durham =

567.6 - (567.6 x 0.93) = 39.7 = 0.4 Summer warmth zones

Estimated DD deviation of Tynemouth from Ushaw =

507.6 - (507.6 x 0.96) = 20.3 = 0.2 Summer warmth zones

Estimated DD deviation of Tynemouth from Chopelwood =

477.8 - (477.8 x 0.93) = 33.5 = 0.3 Summer warmth zones

Estimated DD deviation of Tynemouth from Cockle Park =

477.8 - (477.8 x 0.92) = 38.2 = 0.3 Summer warmth zones

Estimated DD deviation of Tynemouth from Acklington =

537.8 - (537.8 x 0.99) = 5.4 = 0.0 Summer warmth zones

Estimated DD deviation of Tynemouth from Houghall =

627.6 - (627.6 x 0.91) = 56.5 = 0.5 Summer warmth zones

Skegness:

	Alt	Ref Area	DD	May-Oct Mean Month Max °c
Skegness	5	17e	-	22.4
Cranwell	62	17w	773.6	25.3
Lincoln	7	17w	773.6	24.5

Estimated DD deviation of Skegness from Cranwell =

773.6 - (773.6 x 0.96) = 31.0 = 0.3 Summer warmth zones

Estimated DD deviation of Skegness from Lincoln =

773.6 - (773.6 x 0.95) = 38.7 = 0.3 Summer warmth zones

Clacton:

	Alt	Ref Area	DD	May-Oct Mean Month Max °c
Clacton	16	33e	-	22.4
Earles Colne	49	33e	852.6	25.3
Cambridge B.G	12	28	834.4	25.7
Maldon	4	33e	852.6	25.1
Writtle	32	33e	852.6	25.3

Estimated DD deviation of Clacton from Earles Colne =

852.6 - (852.6 x 0.88) = 102.3 = 0.9 Summer warmth zones

Estimated DD deviation of Clacton from Cambridge B.G =

834.4 - (834.4 x 0.87) = 108.5 = 1.0 Summer warmth zones

Estimated DD deviation of Clacton from Maldon =

852.6 - (852.6 x 0.89) = 93.8 = 0.8 Summer warmth zones

Estimated DD deviation of Clacton from Writtle =

852.6 - (852.6 x 0.88) = 102.3 = 0.9 Summer warmth zones

Dover:

	Alt	Ref Area	DD	May-Oct Mean Month Max °c
Dover	6	39e	-	23.1
Wye	56	39w	874.5	24.7
Bodiam	22	38n	848.5	24.8

Estimated DD deviation of Dover from Wye =

874.5 - (874.5 x 0.93) = 61.2 = 0.5 Summer warmth zones

Estimated DD deviation of Dover from Bodiam =

848.5 - (848.5 x 0.93) = 59.4 = 0.5 Summer warmth zones

Bognor:

	Alt	Ref Area	DD	May-Oct Mean Month Max °c
Bognor	7	46	-	22.1
Leckford	117	38n	769.8	24.4
S Farnborough	69	31s	862.9	25.3

Estimated DD deviation of Bognor from Leckford =

769.8 - (769.8 x 0.90) = 77.0 = 0.7 Summer warmth zones

Estimated DD deviation of Bognor from S Farnborough =

862.9 - (862.9 x 0.87) = 112.2 = 1.0 Summer warmth zones

Sidmouth:

	Alt	Ref Area	DD	May-Oct Mean Month Max °c
Sidmouth	10	45w	-	22.2
Exeter Airport	32	45w	816.2	23.5

Estimated DD deviation of Sidmouth from Exeter Airport =

816.2 - (816.2 x 0.94) = 48.8 = 0.4 Summer warmth zones

Weston S Mare:

	Alt	Ref Area	DD	May-Oct Mean Month Max °c
Weston S Mare	9	30	-	23.9
Long Ashton	51	30	879.9	24.3

Estimated DD deviation of Weston S Mare from Long Ashton

879.9 - (879.9 x 0.98) = 17.6 = 0.2 Summer warmth zones

Colwyn Bay:

	Alt	Ref Area	DD	May-Oct Mean Month Max °c
Colwyn Bay	36	14	-	22.4
Hawarden Bridge	5	14	787.0	24.1
Wrexham	58	14	787.0	23.6

Estimated DD deviation of Colwyn Bay from Hawarden Bridge =

787.0 - (787.0 x 0.93) = 55.1 = 0.5 Summer warmth zones

Estimated DD deviation of Colwyn Bay from Wrexham =

787.0 - (787.0 x 0.95) = 39.4 = 0.3 Summer warmth zones

Appendix II

Dimensions and Characteristics of Models used in Solar Radiation Models

All models have a photosynthetic surface area of 5 m^2.

Given values refer to the area component sides and are in m^2

a) Free standing cube: 1.0 + 1.0 + 1.0 + 1.0 + 1.0

b) Free standing stacked cube: 0.55 + 1.11 + 1.11+ 1.11 + 1.11

c) Wall attached cube: 1.25 + 1.25 + 1.25 + 1.25

d) Wall attached stacked cube: 0.71 + 1.43 + 1.43+ 1.43 + 1.43

e) Wall attached narrow cube: 2.86 + 0.71 + 0.71 + 0.71

f) Wall attached square: 5.0

Derivation of data for 3D radiation canopy models

Data derived from CIBS (1979)

1 Total radiation (direct and diffuse) incident upon a horizontal surface in $w.m^{-2}$

Month	50 N	55 N
April	265.0	245.0
May	320.0	315.0
June	345.0	340.0
July	320.0	315.0
August	265.0	245.0
September	180.0	155.0
Mean for April-September=	282.5	269.1

2 Radiation incident upon free standing cube:

50 N

	N face	E face	S face	W face	Top	Mean
Apr	25x1.0	135x1.0	165x1.0	135x1.0	265x1.0	145.0
May	45	155	135	155	320	162.0
Jun	55	160	120	160	345	168.0
Jul	45	155	135	155	320	162.0
Aug	25	135	165	135	265	145.0
Sep	15	100	190	100	180	117.0
					Mean =	149.8

55N

Apr	25x1.0	135x1.0	180x1.0	135x1.0	245x1.0	144.0
May	50	160	155	160	315	168.0
Jun	60	170	140	170	340	176.0
Jul	50	160	155	160	315	168.0
Aug	25	135	180	135	245	144.0
Sep	15	95	195	95	155	111.0
					Mean =	151.8

3 Radiation incident upon freestanding stacked cube:

50 N

	N face	E face	S face	W face	Top	Mean
Apr	25x1.11	135x1.11	165x1.11	135x1.11	265x0.55	131.27
May	45	155	135	155	320	143.98
Jun	55	160	120	160	345	147.84
Jul	45	155	135	155	320	143.98
Aug	25	135	165	135	265	131.27
Sep	15	100	190	100	180	109.71
					Mean =	134.7

55 N

Apr	25x1.11	135x1.11	180x1.11	135x1.11	245x0.55	132.40
May	50	160	155	160	315	151.20
Jun	60	170	140	170	340	157.28
Jul	50	160	155	160	315	151.20
Aug	25	135	180	135	245	132.40
Sep	15	95	195	95	155	102.10
					Mean =	137.8

4 Radiation incident on cube against N wall:

50 N

	N face	E face	S face	W face	Top	Mean
Apr	25x1.25	135x1.25	-	135x1.25	265x1.25	140.00
May	45	155	-	155	320	168.75
Jun	55	160	-	160	345	180.00
Jul	45	155	-	155	320	168.75
Aug	25	135	-	135	265	140.00
Sep	15	100	-	100	180	98.75
					Mean =	149.4

55 N

Apr	25x1.25	135x1.25	-	135x1.25	245x1.25	135.00
May	50	160	-	160	315	171.50
Jun	60	170	-	170	340	185.00
Jul	50	160	-	160	315	171.50
Aug	25	135	-	135	245	135.00
Sep	15	95	-	95	155	90.00
					Mean =	147.9

5 Radiation incident upon stacked cube against N wall:

50 N

	N face	E face	S face	W face	Top	Mean
Apr	25x1.43	135x1.43	-	135x1.42	265x0.71	122.00
May	45	155	-	155	320	146.97
Jun	55	160	-	160	345	156.24
Jul	45	155	-	155	320	146.97
Aug	25	135	-	135	265	122.00
Sep	15	100	-	100	180	87.05
					Mean =	130.2

55 N

Apr	25x1.43	135x1.43	-	135x1.43	245x0.71	119.16
May	50	160	-	160	315	150.55
Jun	60	170	-	170	340	162.68
Jul	50	160	-	160	315	150.75
Aug	25	135	-	135	245	119.16
Sep	15	95	-	95	155	80.64
					Mean =	130.4

6 Radiation incident upon narrow cube against N wall:

50 N

	N face	E face	S face	W face	Top	Mean
Apr	25x2.86	135x0.71	-	135x0.71	265x0.71	90.27
May	45	155	-	155	320	115.20
Jun	55	160	-	160	345	125.88
Jul	45	155	-	155	320	115.20
Aug	25	135	-	135	265	90.27
Sep	15	100	-	100	180	62.54
					Mean =	99.9

55 N

Apr	25x2.86	135x0.71	-	135x0.71	245x0.71	87.43
May	50	160	-	160	315	118.77
Jun	60	170	-	170	340	130.88
Jul	50	160	-	160	315	118.77
Aug	25	135	-	135	245	87.43
Sep	15	95	-	95	155	57.45
					Mean =	100.1

7 Radiation incident upon a square against a N wall:

50 N

	N face	E face	S face	W face	Top	Mean
Apr	25x5.0	-	-	-	-	25.00
May	45	-	-	-	-	45.00
Jun	55	-	-	-	-	55.00
Jul	45	-	-	-	-	45.00
Aug	25	-	-	-	-	25.00
Sep	15	-	-	-	-	15.00
					Mean =	35.0

55 N

Apr	25x5.0	-	-	-	-	25.00
May	50x5.0	-	-	-	-	50.00
Jun	60x5.0	-	-	-	-	60.00
Jul	50x5.0	-	-	-	-	50.00
Aug	25x5.0	-	-	-	-	25.00
Sep	15x5.0	-	-	-	-	15.00
					Mean =	37.5

8 Radiation incident upon cube against E or W facing wall:

50 N

	N face	E face	S face	W face	Top	Mean
Apr	25x1.25	135x1.25	165x1.25	-	265x1.25	147.50
May	45	155	135	-	320	163.75
Jun	55	160	120	-	345	170.00
Jul	45	155	135	-	320	163.75
Aug	25	135	165	-	265	147.50
Sep	15	100	190	-	180	121.25
					Mean =	152.3

55 N

Apr	25x1.25	135x1.25	180x1.25	-	245x1.25	146.25
May	50	160	155	-	315	170.00
Jun	60	170	140	-	340	177.44
Jul	50	160	155	-	315	146.25
Aug	25	135	180	-	245	146.25
Sep	15	95	195	-	155	114.99
					Mean =	154.1

9 Radiation incident upon stacked cube against E or W wall

50 N

	N face	E face	S face	W face	Top	Mean
Apr	25x1.43	135x1.43	165x1.43	-	265x0.71	130.58
May	45	155	135	-	320	141.25
Jun	55	160	120	-	345	141.80
Jul	45	155	135	-	320	141.25
Aug	25	135	165	-	265	130.58
Sep	15	100	190	-	180	112.79
					Mean =	133.5

55 N

Apr	25x1.43	135x1.43	180x1.43	-	245x0.71	132.03
May	50	160	155	-	315	149.12
Jun	60	170	140	-	340	154.10
Jul	50	160	155	-	315	149.12
Aug	25	135	180	-	245	132.03
Sep	15	95	195	-	155	109.24
					Mean =	137.6

10 Radiation incident upon narrow cube against E or W wall:

50 N

	N face	E face	S face	W face	Top	Mean
Apr	25x0.71	135x2.86	165x0.71	-	265x0.71	141.83
May	45	155	135	-	320	159.66
Jun	55	160	120	-	345	165.36
Jul	45	155	135	-	320	159.66
Aug	25	135	165	-	265	141.83
Sep	15	100	190	-	180	111.87
					Mean =	145.7

55 N

Apr	25x0.71	135x2.86	180x0.71	-	245x0.71	141.12
May	50	160	155	-	315	162.51
Jun	60	170	140	-	340	173.92
Jul	50	160	155	-	315	162.51
Aug	25	135	180	-	245	141.12
Sep	15	95	195	-	155	106.17
					Mean =	147.9

11 Radiation incident upon square against E or W wall:

50 N

	N face	E face	S face	W face	Top	Mean
Apr	-	135x5.0	-	-	-	135.00
May	-	155	-	-	-	155.00
Jun	-	160	-	-	-	160.00
Jul	-	155	-	-	-	155.00
Aug	-	135	-	-	-	135.00
Sep	-	100	-	-	-	100.00
					Mean =	140.00

55 N

Apr	-	135x5.0	-	-	-	135.00
May	-	160	-	-	-	160.00
Jun	-	170	-	-	-	170.00
Jul	-	160	-	-	-	160.00
Aug	-	135	-	-	-	135.00
Sep	-	100	-	-	-	100.00
					Mean =	142.4

12 Radiation incident upon cube against S facing wall:

50 N

	N face	E face	S face	W face	Top	Mean
Apr	-	135x1.25	165x1.25	135x1.25	265x1.25	175.00
May	-	155	135	155	320	191.25
Jun	-	160	120	160	345	196.25
Jul	-	155	135	155	320	191.25
Aug	-	135	165	135	265	175.00
Sep	-	100	190	100	180	142.50
					Mean =	178.5

55 N

Apr	-	135x1.25	180x1.25	135x1.25	245x1.25	173.75
May	-	160	155	160	315	147.50
Jun	-	170	140	170	340	205.00
Jul	-	160	155	160	315	147.50
Aug	-	135	180	135	245	173.75
Sep	-	95	195	95	155	134.99
					Mean =	180.4

13 Radiation incident upon stacked cube against S facing wall

50 N

	N face	E face	S face	W face	Top	Mean
Apr	-	135x1.43	165x1.43	135x1.43	265x0.71	162.04
May	-	155	135	155	320	172.71
Jun	-	160	120	160	345	174.83
Jul	-	155	165	155	320	172.71
Aug	-	135	165	135	265	162.04
Sep	-	100	190	100	180	137.10
					Mean =	163.4

55 N

Apr	-	135x1.43	180x1.43	135x1.43	245x0.71	163.49
May	-	160	155	160	315	180.58
Jun	-	170	140	170	340	185.56
Jul	-	160	155	160	315	180.58
Aug	-	135	180	135	245	163.49
Sep	-	95	195	95	155	132.11
					Mean =	167.6

14 Radiation incident upon narrow cube against a S facing wall:

50 N

	N face	E face	S face	W face	Top	Mean
Apr	-	135x0.71	165x2.86	135x0.71	265x0.71	170.34
May	-	155	135	155	320	166.68
Jun	-	160	120	160	345	163.07
Jul	-	155	135	155	320	166.68
Aug	-	135	165	135	265	170.34
Sep	-	100	190	100	180	160.82
					Mean =	166.3

55 N

Apr	-	135x0.71	180x2.86	135x0.71	245x0.71	176.69
May	-	160	155	160	315	178.83
Jun	-	170	140	170	340	176.64
Jul	-	160	155	160	315	178.83
Aug	-	135	180	135	245	176.69
Sep	-	95	195	95	155	161.53
					Mean =	174.9

15 Radiation incident upon square against a S facing wall:

50 N

	N face	E face	S face	W face	Top	Mean
Apr	-	-	165x5.0	-	-	165.00
May	-	-	135	-	-	135.00
Jun	-	-	120	-	-	120.00
Jul	-	-	135	-	-	135.00
Aug	-	-	165	-	-	165.00
Sep	-	-	190	-	-	190.00
					Mean =	151.7

55 N

Apr	-	-	180x5.0	-	-	180.00
May	-	-	155	-	-	155.00
Jun	-	-	140	-	-	140.00
Jul	-	-	155	-	-	155.00
Aug	-	-	180	-	-	180.00
Sep	-	-	195	-	-	195.00
					Mean =	167.5

SECTION 1 Please answer all the questions. Tick boxes as appropriate.

1. Name and address of the garden ?.................................... FORDE ABBEY CHARD

2. Position of person completing the questionnaire ?...Owner......

3. Height above sea level ?

0-75m (0-245 ft)	
75-150m (2.45-490 ft)	✓
150-225m (490-737 ft)	
225-300m (737-983 ft)	

4. Slope ?

garden flat	
garden sloping	
garden undulating	✓
garden at bottom of a valley	

5. Severity of slope ?

gentle, less than 10° (1 in 5)	✓
steep. greater than 10° (1 in 5)	

6. (sloping gardens only) Aspect ?

N,NE,NW facing	✓
S,SE,SW facing	
E facing	
W facing	

7. (sloping gardens only) Do buildings/hedges/shrub masses further down the slope impede the drainage of cold air away from the garden ?

Probably.

yes	
no	

8. Area surrounding the garden ?

extensive arable agriculture	
agriculture/woodland	✓
woodland	
heath/moor	
suburban	
urban	

9. Wind shelter within the garden ?

exposed	
partially sheltered	✓
very sheltered	

10. General soil type within the garden ?

heavy, water retentive	
light, free draining	✓

11. Soil pH ?

acid	✓
neutral	

IMPORTANT Please read these instructions before you work through Section 2.

1. Read through the list of plants underlining any that you grow or have grown. This will reduce the questionnaire to a short list which will be much less daunting to work through. **

2.a Return to the first name you underlined and start by ticking as many boxes as necessary under the heading "PLANTING SITE IS" in order to provide as complete a picture as possible of the planting/growing site. Where the column headings contain the symbol "/" this should be read as "or".

Note if this first set of boxes is left blank any following information on plant hardiness is meaningless.

b Indicate how the plant responds to this planting/growing site by ticking box(es) under the heading, 'UNDER YOUR CONDITIONS THIS PLANT IS :'

For example :

If you grew Abutilon suntense against a shaded, sheltered wall where it had proved hardy and grew well, but flowered poorly, or not at all, then you would record this information as follows :

	PLANTING SITE IS :							UNDER YOUR CONDITIONS THIS PLANT IS :			
	wall	shaded	woodland/shrubbery/fence	lawn/paving	exposed	sheltered	frost pocket	NOT HARDY	HARDY: Grows satisfactorily	HARDY: Doesnt grow satisfactorily	HARDY: Doesnt flow satisfactor
Abelia floribunda	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Abutilon megapotamicum	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
" suntense	✓	✓	☐	☐	☐	✓	☐	☐	✓	☐	✓
" vitifolium	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Acacia baileyana	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
" dealbata	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
" pravissima	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐

c For the purpose of the questionnaire please consider a plant as 'Hardy' if under your conditions the aerial parts do not exhibit winter damage beyond leaf scorch or the death of the tips of last season's extension growth.

d A plant should be entered as 'Not Hardy' if under your conditions it is subject to more extensive winter damage than the above, eg. severe bark split to the death of part or all of the branch structure.

Note with subshrubs such as Caryopteris, Ceratostigma, Fuchsia plants can be considered 'Hardy' if they regenerate from, or below soil level following the death of the aerial parts.

e The column headed 'Doesn't grow satisfactorily' refers to plants that are basically winter hardy, but don't grow well for other reasons, eg. this might be due to low rainfall; insufficient sunshine; spring frosts; exposed growing position. Please document additional limiting factors that are important in your garden, under 'Comments' (page 14).

3.a Only include information for plants that have been established in your garden for a minimum of 5 years. For plants which have failed, eg. are not hardy, only enter information on plants which have been established for at least one growing season in your garden. (prior to failure)

b With species that only switch to flower production after many years' vegetative growth, eg. Davidia, the approximate ages of any such plants will prove valuable and may be entered under 'Comments' (page 14), or in numerals next to the plant name.

4 Where additional protection in the form of polythene drapes etc. has been provided please make a note of this under 'Comments' (page 14).

5 Where a plant name is followed by & cvs ,it is equally acceptable to document the response of cultivars of that species.

indicate the characteristics of the planting / growing site and the response of the plant to this position.

	PLANTING SITE IS :							UNDER YOUR CONDITIONS THIS PLANT IS :	HARDY		
	wall	shaded	woodland/shrubbery/fence	lawn/paving	exposed	sheltered	frost pocket	NOT HARDY	Grows satisfactorily	Doesnt grow satisfactorily	Doesnt flow satisfactor
Abelia floribunda											
Abutilon megapotamicum	X								X		
" suntense											
" vitifolium											
Acacia baileyana											
" dealbata											
" pravissima											
" riceana											
Akebia quinata											
Albizia julibrissin 'Rosea'											
Arbutus andrachnoides											
" menziesii											
Artemisia arborescens											
Azara microphylla 'Variegata'											
Berberidopsis corallina											
Billardia longiflora											
Buddleia colvilei 'Kewensis'											
Caesalpinia japonica											
Callistemon citrinus											
" rigidus											
" subulatus											
Campis 'Mme. Galen'											
Camellia reticulata & cvs			X						X		

	PLANTING SITE IS :							UNDER YOUR CONDITIONS THIS PLANT IS :	HARDY		
	wall	shaded	woodland/shrubbery/fence	lawn/paving	exposed	sheltered	frost pocket	NOT HARDY	Grows satisfactorily	Doesnt grow satisfactorily	Doesnt flowe satisfactori
Ceanothus impressus	X								X		
" lobbianus											
" papillosus											
" veitchianus											
Cercidiphyllum japonicum					X				only fair		
Cestrum parqui											
Chimonanthus praecox											
Chionanthus retusus											
" virginicus											
Cistus aguilari											
" corbariensis											
" ladanifer											
" purpureus											
" 'Silver Pink'											
Clethra arborea											
" delavayii											
" fargesii											
Clematis cirrhosa balearica											
Clianthus puniceus											
Cordyline australis											
Cornus capitata											
" florida			X						X		
Corokia virgata											

	PLANTING SITE IS :							UNDER YOUR CONDITIONS THIS PLANT IS :			
								NOT HARDY	HARDY		
	wall	shaded	woodland/shrubbery/fence	lawn/paving	exposed	sheltered	frost pocket		Grows satisfactorily	Doesnt grow satisfactorily	Doesnt flower satisfactoril
Cunninghamia lanceolata	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Cupressus cashmiriana	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Cuppressus lusitanica	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Danae racemosa	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Daphniphyllum macropodum ...	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Desfontainea spinosa	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Diospyros khaki	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Dicksonia antartica.........	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Drimys winteri	☐	☐	☒	☐	☐	☐	☐	☐	☐	☒	☐
Erythrina crista galli	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Erica australis	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
" canaliculatus	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
" lusitanica	☐	☐	☐	☐	☐	☒	☐	☐	☒	☐	☐
" veitchii 'Exeter'	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Escallonia 'Iveyi'	☐	☐	☐	☐	☐	☒	☐	☐	☒	☐	☐
Eucryphia cordifolia	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Eucalyptus coccifera	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
" dalrympleana	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
" glaucescens	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
" globulus	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
" nitens	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
" perriniana	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
" urnigera	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Fabiana imbricata	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐

	PLANTING SITE IS :							UNDER YOUR CONDITIONS THIS PLANT IS :	HARDY		
	wall	shaded	woodland/shrubbery/fence	lawn/paving	exposed	sheltered	frost pocket	NOT HARDY	Grows satisfactorily	Doesnt grow satisfactorily	Doesnt flow satisfactor
Feijoa sellowiana	X								X		
Fremontodendron californicum											
Gleditsia t. 'Sunburst '											
Griselina lit. 'Variegata '											
Halimiocistus wintonensis											
Hebe andersonii 'Variegata'											
" 'Great Orme'											
" hulkeana											
" 'Midsummer Beauty'											
" salicifolia											
" speciosa cvs											
Hoheria glabrata											
" lyalli											
" sexstylosa											
Hypericum moserianum 'Tricolor'											
" 'Rowallane'	X									X	
Idesia polycarpa											
Itea illicifolia											
Jasminum polyanthum											
Kalmia latifolia			X						X		
Koelreuteria paniculata											
Lavateria olbia 'Rosea'					X				X		
Lapageria rosea											
Leptospermum scoparium cvs											

	PLANTING SITE IS :							UNDER YOUR CONDITIONS THIS PLANT IS :	HARDY		
	wall	shaded	woodland/shrubbery/fence	lawn/paving	exposed	sheltered	frost pocket	NOT HARDY	Grows satisfactorily	Doesnt grow satisfactorily	Doesnt flow[er] satisfactor[ily]
Lithocarpus henryi											
Lomatia ferruginea											
Mahonia acanthifolia											
Magnolia delavayi											
Mandevilla suavolens											
Meliosma veitchorum											
Muehlenbeckia complexa											
Myrtus apiculata (luma)											
" communis & cvs											
Olearia avicennifolia											
" macrodonta											
" phlogopappa											
" semidentata											
" solandri											
" stellulata 'Splendens'											
" traversii											
" 'Zennorensis'											
Oxydendrum arboreum											
Passiflora caerulea											
Paulownia tomentosa											
Pieris forrestii 'wakehurst'											
Pileostegia viburnoides											
Pinus montezumae						X			X		
" patula											

Plant	PLANTING SITE IS : wall	shaded	woodland/shrubbery/fence	lawn/paving	exposed	sheltered	frost pocket	UNDER YOUR CONDITIONS THIS PLANT IS : NOT HARDY	HARDY: Grows satisfactorily	HARDY: Doesnt grow satisfactorily	HARDY: Doesnt flowe satisfactori
Pittosporum eugenoides											
" e. 'Variegatum'											
" patulum											
" tennuifolium											
" t. 'Silver Queen'											
" t. 'Purpureum'											
" tobira											
Podocarpus macrophyllus											
" salignus											
Punica granatum											
Quercus suber											
Raphiolepis delacourii											
Ribes speciosum											
Rosa brunonii 'La Mortola'											
" 'Mermaid'											
Rosmarinus lavandulaceus											
Senecio reinoldii											
Solanum crispum	X									X	
" jasminoides											
Sophora japonica											
" tetratera											
Stachyurus chinensis & cv	X								X		
Telopea truncata											
Teucrium fruticans	X								X		

	PLANTING SITE IS : wall	shaded	woodland/shrubbery/fence	lawn/paving	exposed	sheltered	frost pocket	UNDER YOUR CONDITIONS THIS PLANT IS : NOT HARDY	HARDY: Grows satisfactorily	HARDY: Doesnt grow satisfactorily	HARDY: Doesnt flowe[r] satisfactori[ly]
Trachelospermum asiaticum...											
" jasminoides											
Viburnum cinnamonifolium ...											
" macrocephalum											
" grandiflorum.......											
" henryi											
" tinus 'Variegatum'											
Wisteria floribunda & cvs...											
<u>Any additional shrubs/trees in your garden that you think might be of interest to this survey ?</u> :											

Are you willing to continue your involvement in this study ?

This might involve a small amount of correspondence or a visit to your garden.

yes ☐

no ☐

Any additional relevant comments ?

Several of these plants grow entirely satisfactorily on a wall but we do tend to lose them in a hard winter. This is really a quite frosty garden.

Thank you very much for giving up so much of your valuable time in completing this questionnaire.

SECTION 1 Please answer all the questions. Tick boxes as appropriate.

1. Name and address of the garden ?..B.P. TORRSETT..............
......CRITTENDEN.......Matfield.....TONBRIDGE Kent

2. Position of person completing the questionnaire ?...Owner........

3. Height above sea level ?

0-250 ft (0-75m)	250
250-500 ft (75-152m)	
500-1000 ft (152-304m)	

4. Slope ?

garden flat	
garden sloping	
garden undulating	✓
garden at bottom of a valley	

5. Severity of slope ?

gentle, less than 10° (1 in 5)	about 10°
steep. greater than 10° (1 in 5)	

6. (sloping gardens only) Aspect ?

N,NE,NW facing	
S,SE,SW facing	✓
E facing	
W facing	

7. (sloping gardens only) Do buildings/hedges/shrub masses further down the slope impede the drainage of cold air away from the garden ?

yes	
no	✓

8. Area surrounding the garden ?

extensive arable agriculture	
agriculture/woodland	✓
woodland	
heath/moor	
suburban	
urban	

9. Wind shelter within the garden ?

exposed	
partially sheltered	✓
very sheltered	

10. General soil type within the garden ?

heavy, water retentive	✓
light, free draining	

11. Soil pH ?

Varies greatly

acid	
neutral	✓
alkaline	

<u>IMPORTANT</u> Please read these instructions <u>before</u> you work through <u>Section 2</u>.

1. Read through the list of plants underlining any that you grow or have grown. This will reduce the questionnaire to a short list which will be much less daunting to work through.

** **

2.a Return to the first name you underlined and start by ticking as many boxes as necessary under the heading "<u>PLANTING SITE IS</u>" in order to provide as complete a picture as possible of the planting/growing site. Where the column headings contain the symbol "/" this should be read as "or".

<u>Note</u> if this first set of boxes is left blank any following information on plant hardiness is meaningless.

b Indicate how the plant responds to this planting/growing site by ticking box(es) under the heading, '<u>UNDER YOUR CONDITIONS THIS PLANT IS</u> :'

<u>For example</u> :

If you grew <u>Akebia trifoliata</u> against a shaded, sheltered wall where it had proved hardy and grew well, but flowered poorly, or not at all, then you would record this information as follows :

	PLANTING SITE IS :							UNDER YOUR CONDITIONS THIS PLANT IS :			
								NOT HARDY	HARDY		
	wall	shaded	woodland/shrubbery/fence	lawn/paving	exposed	sheltered	frost pocket		grows satisfactorily	doesnt grow satisfactorily	doesnt flower satisfactorily
ia grandiflora	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
ilon suntense	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
lobelli	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
ulus indica	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
neglecta'Erythroblastos	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
ia trifoliata	☑	☑	☐	☐	☐	☐	☐	☐	☑	☐	☑
tus andrachnoides	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐

c For the purpose of the questionnaire please consider a plant as '<u>Hardy</u>' if under your conditions the aerial parts do not exhibit winter damage beyond leaf scorch or the death of the tips of last season's extension growth.

d A plant should be entered as '<u>Not Hardy</u>' if under your conditions it is subject to more extensive winter damage than the above, eg. severe bark split to the death of part or all of the branch structure.

<u>Note</u> with subshrubs such as <u>Caryopteris, Ceratostigma, Fuchsia</u> plants can be considered 'Hardy' if they regenerate from, or below soil level following the death of the aerial parts.

e The column headed '<u>Doesn't grow satisfactorily</u>' refers to plants that are basically winter hardy, but don't grow well for other reasons, eg. this might be due to low rainfall; insufficient sunshine; spring frosts; exposed growing position. Please document additional limiting factors that are important in your garden, under 'Comments' (page 14).

3.a Only include information for plants that have been established in your garden for a minimum of 5 years. For plants which have failed, eg. are not hardy, only enter information on plants which have been established for at least one growing season in your garden. (prior to failure)

b With species that only switch to flower production after many years' vegetative growth, eg. <u>Davidia</u>, the approximate ages of any such plants will prove valuable and may be entered under 'Comments' (page 14), or in numerals next to the plant name.

4 Where additional protection in the form of polythene drapes etc. has been provided please make a note of this under 'Comments' (page 14).

5 Where a plant name is followed by <u>& cvs</u> ,it is equally acceptable to document the response of cultivars of that species.

characteristics of the planting/growing site and the response of the plant to this position.

	PLANTING SITE IS :							UNDER YOUR CONDITIONS THIS PLANT IS :	HARDY		
	wall	shaded	woodland/shrubbery/fence	lawn/paving	exposed	sheltered	frost pocket	NOT HARDY	grows satisfactorily	doesnt grow satisfactorily	doesnt flower satisfactorily
Abelia grandiflora						✓			✓		
Abutilon suntense											
Acer lobelli											
Aesculus indica					✓				✓		
" neglecta'Erythroblastos											
Akebia trifoliata											
Arbutus andrachnoides											
" menziesii						✓			✓		
" unedo						✓			✓		
Arundinaria anceps											
Azara microphylla						✓			✓		
Berberidopsis corallina											
Berberis valdiviana											
Buddleia colvilei'Kewensis'											
" fallowiniana						✓			✓		
" globosa					✓				✓		
Caesalpinia japonica											
Carpenteria californica						✓		✓			
Caryopteris clandonensis						✓				✓	
Catalpa bignonoides						✓			✓		
" fargesii											
" speciosus											
Ceanothus burkwoodii											
" 'Cascade'											
" 'Edinburgh'											

	PLANTING SITE IS :							UNDER YOUR CONDITIONS THIS PLANT IS :			
								NOT HARDY	HARDY		
	wall	shaded	woodland/shrubbery/fence	lawn/paving	exposed	sheltered	frost pocket		grows satisfactorily	doesnt grow satisfactorily	doesnt flower satisfactorily
Ceanothus'Gloire de Versaille	✓								✓		
" 'Henri Defosse'	✓								✓		
" impressus						✓			✓		
" thyrsiflorus											
" veitchianus											
Cedrus deodara					✓				✓		
Cephalotaxus harringtoniana											
Ceratostigma willmotianum						✓			✓		
Cercis siliquastrum					✓				✓		
Cercidiphyllum japonicum		✓						✓			
Chimonanthus praecox						✓			✓		
Chionanthus retusus											
" virginicus											
Cistus corbariensis											
" cyprius											
" ladanifer											
" laurifolius						✓			✓		
Chusquea couleou											
Clerodendron bungei						✓				✓	
" trichotomum											
Clethra delavayii											
" fargesii						✓			✓		
Clematis armandii											
" cirrhosa balearica											
Colletia armata			✓						✓		

	PLANTING SITE IS :							UNDER YOUR CONDITIONS THIS PLANT IS :	HARDY		
	wall	shaded	woodland/shrubbery/fence	lawn/paving	exposed	sheltered	frost pocket	NOT HARDY	grows satisfactorily	doesnt grow satisfactorily	doesnt flower satisfactorily
Cornus alternifolia'Argentea											
" florida			✓					X			
" kousa chinensis			✓					X			
" nuttallii											
Corokia virgata	✓								✓		
Corylopsis pauciflora			✓						✓		
Cunninghamia lanceolata											
Cuppressus lusitanica											
" macrocarpa & cvs											
" sempervirens											
Cytisus battandieri			✓							✓	
Daboecia 'William Buchanan'											
Danae racemosa											
Daphniphyllum macropodum											
Desfontainea spinosa	✓							✓			
Diospyros khaki											
Deutzia hybrida cvs			✓						✓		
Embothrium coc.'Norquinco Val			✓						✓		
Erica alpina'Arborea'											
Erythrina crista-galli											
Escallonia 'Apple Blossom'			✓						✓		
" 'Donard Radiance'											
" 'Gwendolyn Anley'											
Eucalptus coccifera											
" glaucesens											

	PLANTING SITE IS :							UNDER YOUR CONDITIONS THIS PLANT IS :			
								NOT HARDY	HARDY		
	wall	shaded	woodland/shrubbery/fence	lawn/paving	exposed	sheltered	frost pocket		grows satisfactorily	doesnt grow satisfactorily	doesnt flower satisfactoril
alptus gunnii											
niphophila											
parviflora											
urnigera											
ryphia int.'Rostrevor'..											
nymansensis''Nymansay'			✓						✓		
nymus grandiflora											
japonica &.cvs.....											
horbia venata (wulfenii)											
iana imbricata											
imb. 'Prostrata' ..											
shedera lizei											
sia japonica............			✓						✓		
us carica											
chia'Corallina'											
magellanica cvs			✓						✓		
'Riccartonii'.........											
'Mrs Popple'			✓						✓		
rya elliptica	✓										
ista aetnensis			✓						✓		
lydia				✓					✓		
ditsia triacanthos											
'Sunburst'			✓						✓		
selina littoralis											
litt. 'Variegata'											

	PLANTING SITE IS :							UNDER YOUR CONDITIONS THIS PLANT IS :			
	wall	shaded	woodland/shrubbery/fence	lawn/paving	exposed	sheltered	frost pocket	NOT HARDY	HARDY: grows satisfactorily	HARDY: doesnt grow satisfactorily	HARDY: doesnt flower satisfactorily
Halimiocistus ingwersii											
" sauchii											
Halimium ocymoides											
" lasianthum											
Hebe albicans											
" armstrongii											
" 'Carl Teschner'											
" 'Edinensis'											
" cuppressoides											
" cassinoides											
" 'Pagei'											
" vernicosa											
Hedera canariensis 'Gloire de Marengo'											
Hibiscus syriacus			✓					✓			
Hoheria glabrata											
" lyalli			✓					✓			
Hydrangea macrophylla cvs											
" quercifolia											
" serrata cvs											
Hypericum 'Hidcote'			✓						✓		
" indoratum 'Elstead'											
" moserianum 'Tricolor'											
Idesia polycarpa											
Ilex verticilliata											
Indigofera gerardiana											

	PLANTING SITE IS: wall	shaded	woodland/shrubbery/fence	lawn/paving	exposed	sheltered	frost pocket	UNDER YOUR CONDITIONS THIS PLANT IS: NOT HARDY	HARDY: grows satisfactorily	HARDY: doesnt grow satisfactorily	HARDY: doesnt flower satisfactorily
Jasminum officinale	✓								✓		
" stephanense											
Kalmia latifolia			✓						✓		
Koelreuteria paniculata											
Laurus nobilis					✓				✓		
Lavateria olbia 'Rosea'											
Leycesteria formosa											
Ligustrum japonicum											
" lucidum											
" quihoui											
" sinense & cvs											
Liquidamber styraciflua			✓						✓		
Liriodendron tulipfera											
Lomatia myricoides			✓						✓		
Lonicera etrusca			✓						✓		
" sempervirens											
" splendida											
Lupinus arboreus											
Magnolia campbellii			✓						✓		
" dawsoniana											
" grandiflora			✓						✓		
" hypoleuca (obovata)											
" sargentiana robusta			✓								
" soulangiana cvs			✓						✓		
" sinensis			✓						✓		

	PLANTING SITE IS :							UNDER YOUR CONDITIONS THIS PLANT IS :	HARDY		
	wall	shaded	woodland/shrubbery/fence	lawn/paving	exposed	sheltered	frost pocket	NOT HARDY	grows satisfactorily	doesnt grow satisfactorily	doesnt flower satisfactorily
Magnolia veitchii											
Mahonia lomariifolia						✓			✓		
" trifoliata glauca											
Meliosma veitchorum											
Muehlenbeckia complexa			✓						✓		
Mutsia oligodon											
Metasequoia glyptostroboides					✓				✓		
Nothofagus betuloides											
" fusca											
" procera											
" solandri											
Nyssa sinensis											
Olearia avicenniifolia											
" haastii			✓						✓		
" macrodonta											
" nummulariifolia											
Osmanthus armatus											
" delavayii					✓				✓		
" fortunei				✓					✓		
" yunnanensis											
Oxydendron arboreum											
Parthenocissus henryana											
Paulownia fargesii											
" tomentosa					✓				✓		
Phellodendron japonicum											

	PLANTING SITE IS :							UNDER YOUR CONDITIONS THIS PLANT IS :	HARDY		
	wall	shaded	woodland/shrubbery/fence	lawn/paving	exposed	sheltered	frost pocket	NOT HARDY	grows satisfactorily	doesnt grow satisfactorily	doesnt flower satisfactorily
Philadelphus agrocalyx											
" microphyllus											
Phlomis fruticosa			✓						✓		
Phormium tenax & cvs						✓			✓		
Photinia fraseri 'Robusta'											
" glabra 'Rubens'											
" serrulata											
Phygelius capensis											
Pieris forrestii 'Wakehurst'			✓						✓		
" 'Forest Flame'											
Pileostegia viburnoides											
Pinus ayachuite			✓						✓		
" coulteri											
" pinea											
" radiata			✓						✓		
Pittosporum dalli											
" eugenoides											
" patulum											
" tennuifolium			✓						✓		
Podocarpus macrophyllus											
" salignus											
Poncirus trifoliata											
Prunus lustitanica 'Azorica'											
" " 'Variegata'											
Punica granatum	✓								✓		

				lawn/paving	exposed	sheltered	frost pocket	NOT HARDY	HARDY: grows satisfactorily	HARDY: doesnt grow satisfactorily	HARDY: doesnt flower satisfactorily
Quercus canariensis	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
" coccinea 'Splendens'	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
" ilex	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
" imbricana	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
" mysinifolia	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
" suber	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Raphiolepis delacourii	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Rhamnus alaterna	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
" " 'Argenteovariegatus	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Rhus potannii	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Ribes laurifolium	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
" speciosum	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Robinia pseudoacacia	☐	☐	☐	☑	☐	☐	☐	☐	☑	☐	☐
" 'Frisia'	☐	☐	☐	☑	☐	☐	☐	☐	☑	☐	☐
" 'Hilleri'	☐	☐	☐	☐	☐	☐	☐	☐	☑	☐	☐
" hispida	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Romneya coulteri	☐	☐	☐	☑	☐	☐	☐	☐	☑	☐	☐
Rosa 'Mermaid'	☐	☐	☐	☑	☐	☐	☐	☐	☑	☐	☐
Rosmarinus officinalis	☐	☐	☐	☑	☐	☐	☐	☑	☐	☐	☐
Ruscus hypoglossum	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Salvia officinalis.........	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Sarcococca ruscifolia	☐	☐	☐	☐	☐	☑	☐	☐	☑	☐	☐
Santolina chamaecyparissus .	☐	☐	☐	☐	☐	☑	☐	☐	☑	☐	☐
" virens	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Sassafras albidum	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐

HORTBASE: INFORMATION RETRIEVAL HANDBOOK

Contents:

1. Introduction

Hortbase is an information system composed of two databases. These are:

Climatebase - provides a prediction of climate for any part of England and Wales. Information is available for 67 reference areas at 5 different altitudes

Plantbase - provides information on the plants contained within the system. Information is currently available on a total of 113 topics for every plant on the database

To retrieve information from the database proceed as follows: NOTE <u>computer generated text is, for reasons of clarity enclosed in quotes</u>

1. Ensure your terminal is switched on.
   Type in your name as registered on the system and press return.

2. The computer will respond by displaying:
   "Password"
   Type in your password and press return

3. The computer will respond with a ready message e.g
   "r 16.58.0.176.0"
   Type in linus and press return, this enters you into the Logical Inquiry and Update System

4. After the Linus prompt "?" type o horti.db
   Press return

5. After the prompt "?" type lila and press return

6. The computer will respond with a different prompt "→". This signifies you have called up the Lila editor and are now ready to retrieve information

Before you proceed you must decide which database you wish to retrieve information from, and when you have done this, what information you require.

The constituent topics of each database are listed in the Contents.

When selecting plants for a specific planting site it is recommended that the user should first consult Climatebase in order to obtain a prediction of the climatic limitations associated with the planting site. This information can then be used in conjunction with Plantbase to ensure that the plants selected can perform satisfactorily in the climatic regime associated with the planting site.

1.1 Syntax of Information Retrieval

To retrieve information it is necessary to construct a retrieval statement. When using Lila this is quite simple and is composed of 3 lines of information. Each line must start with a number.

Line 1

This first line is known as the select line. In the select line you specify the topics you require information on. A select line may contain any combination of topic retrieval names drawn from either Climatebase or Plantbase, but not from both, each separated by a space.

For example:

When you have typed Lila the computer will respond with the prompt " → "

You should then type:

" → "   10 select

followed by the topic names you wish to retrieve information upon, e.g

For Climatebase:

" → " 10 select hardiness_av_0-75m summer_warmth_0-75m
solar_radiation_0-75m

For Plantbase:

" → " 10 select snum name fl_col height

Finally press return.

Line 2

The second line is known as the *from* line, and tells the computer which database the information is to be extracted from.

When you wish to use Climatebase you should type

climate

When you wish to use Plantbase you should type

plant

For example

" →"   20 from climate

or

" →"   20 from plant

Note the line is numbered, finally press return

Line 3

The third line is known as the *where* line, and contains the information that defines the scope of the selection request. This line may contain any Hortbase topic retrieval names each of which must be followed by a relational operator (< > = <= >=) desired topic value, and finally if another retrieval name is to follow a logical operator (+, or, not).

For example:

For Climatebase

" → " 30 where area = "15w"

For Plantbase

" →" 30 where width = "300" & height = "200" &
growth = "2"

Note that topic values in a where line must be enclosed in quotation marks, and that the same topic can be used in both the where and the select line. Do not confuse this with the use of quotation marks to identify computer generated text.

The completed retrieval statement would now be as follows:

For Climatebase

```
10  select hardiness_av_0-75m  summer_warmth_0-75m
    solar_radiation_0-75m
20  from climate
30  where area =  "15w"
```

For Plantbase

```
10  select  snum name fl_col height
20  from plant
30  where width =  "300"  +  height =  "200"
    growth = "2"
```

Now press return.

The computer will respond with a prompt " →"

Type proc and press return

e.g " →" proc

After the prompt type quit and press return

e.g " $\rightarrow$ " quit

This takes you out of the Lila editor and the prompt will be that of Linus

e.g "?"

Now type print, followed by return and the computer will display the information you have requested on your terminal screen.

When you have finised retrieving information type close to close the database

"?" close

The computer will respond by displaying a ready message

e.g "r 17.09 0.183 0"

type logout and press return to exit from the system

2. Climatebase

2.1 Reference Area

Climatebase retrieval name = area

This is the primary key for Climatebase. England and Wales has been divided into 67 reference areas, as illustrated in Fig 1. To find out which reference your planting site is in, turn to the appropriate location map (Figs 2 to 11) and via the 1:50,000 Ordnance Survey grid overlay locate which area your site falls within. This is then the reference area for you Climatebase enquiries.

2.2 Zonation of Average Winter Cold

Climatebase retrieval name(s) = hardiness_av_0-75m
hardiness_av_75-150m
hardiness_av_150-225m
hardiness_av_225-300m
hardiness_av_300-375m

Corresponding topic on Plantbase = hardiness

This topic records for each reference area the intensity of winter cold that is likely to be experienced in a meteorologically average winter.

The information is recorded via a zone rating derived from the scale 1 (coldest) to 16 (warmest).

Fig. 1 Reference Areas of Climatebase

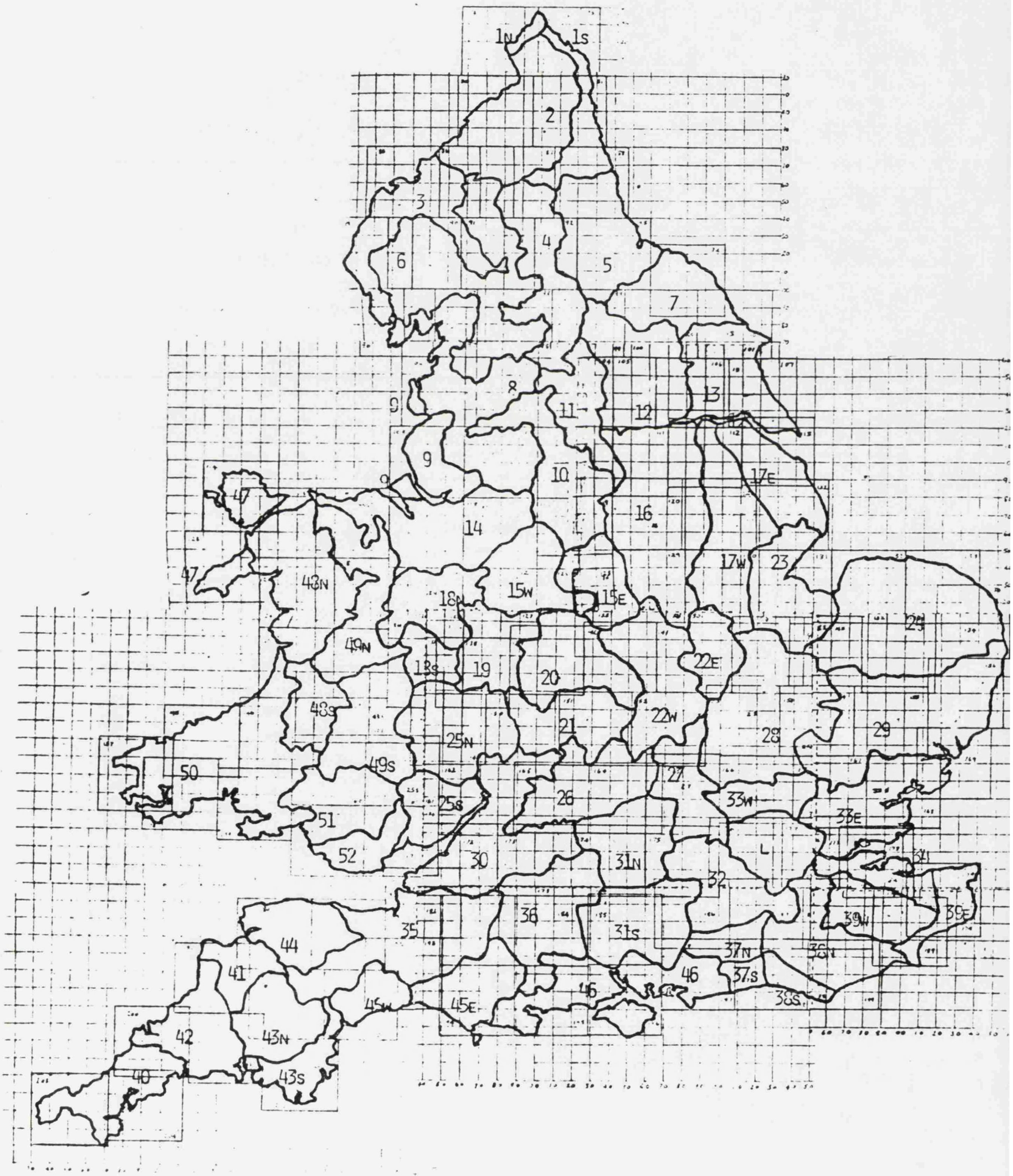


Fig.2 Northumberland and the Borders

Small Numerals on the grid = 1:50,000 Ordnance Survey Sheet Number

Small Numerals at the edges of grid = 1:50,000 Ordnance Survey Grid Co-ordinates

Large Numerals = Reference Areas of Climatebase

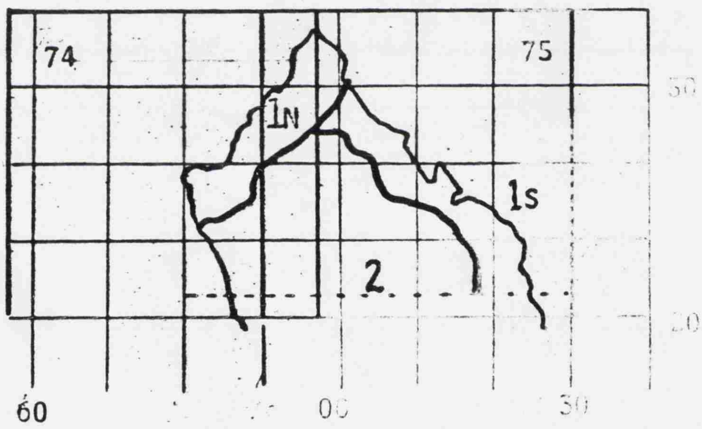


Fig.3 Northern England

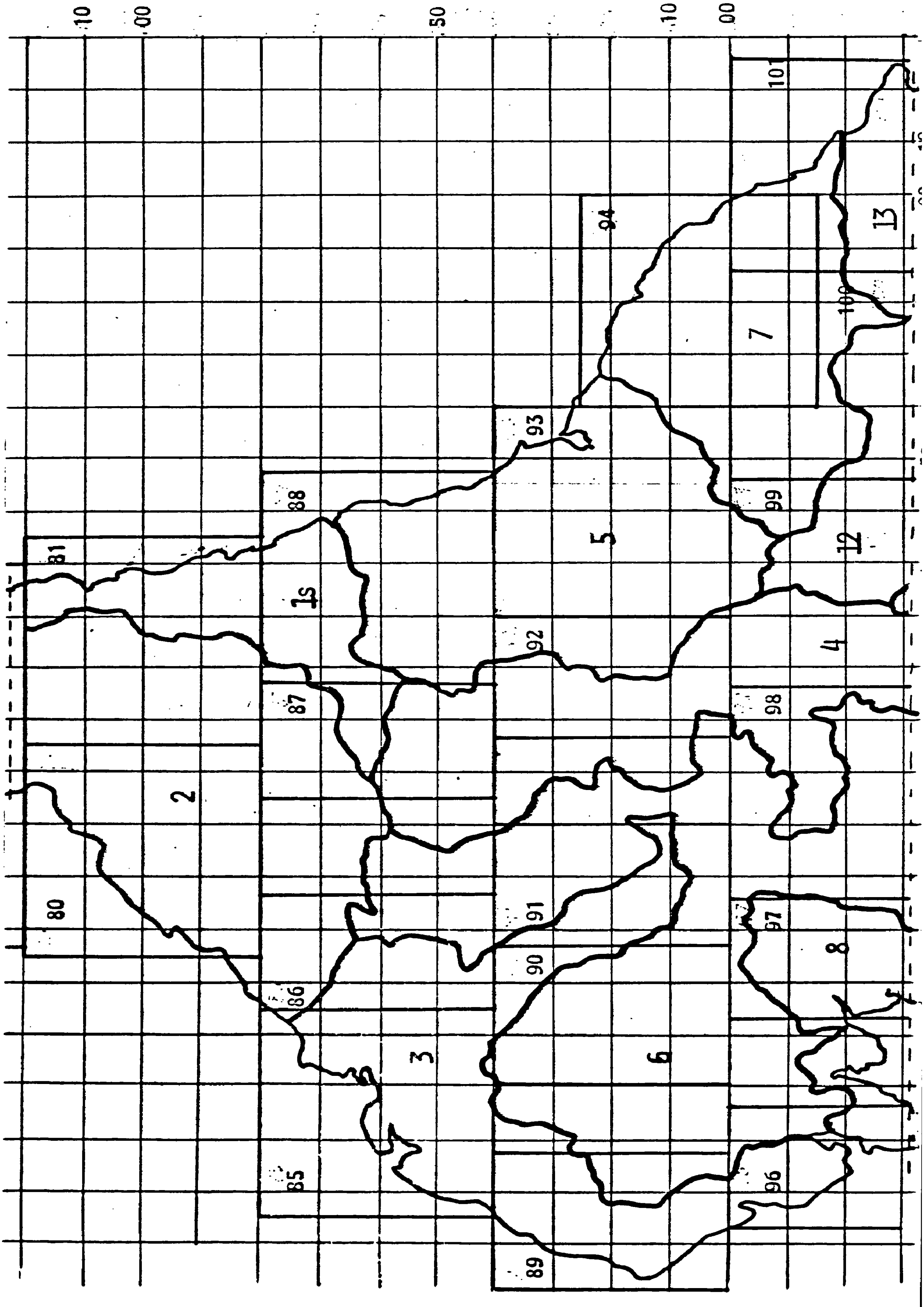


Fig.4 North Wales

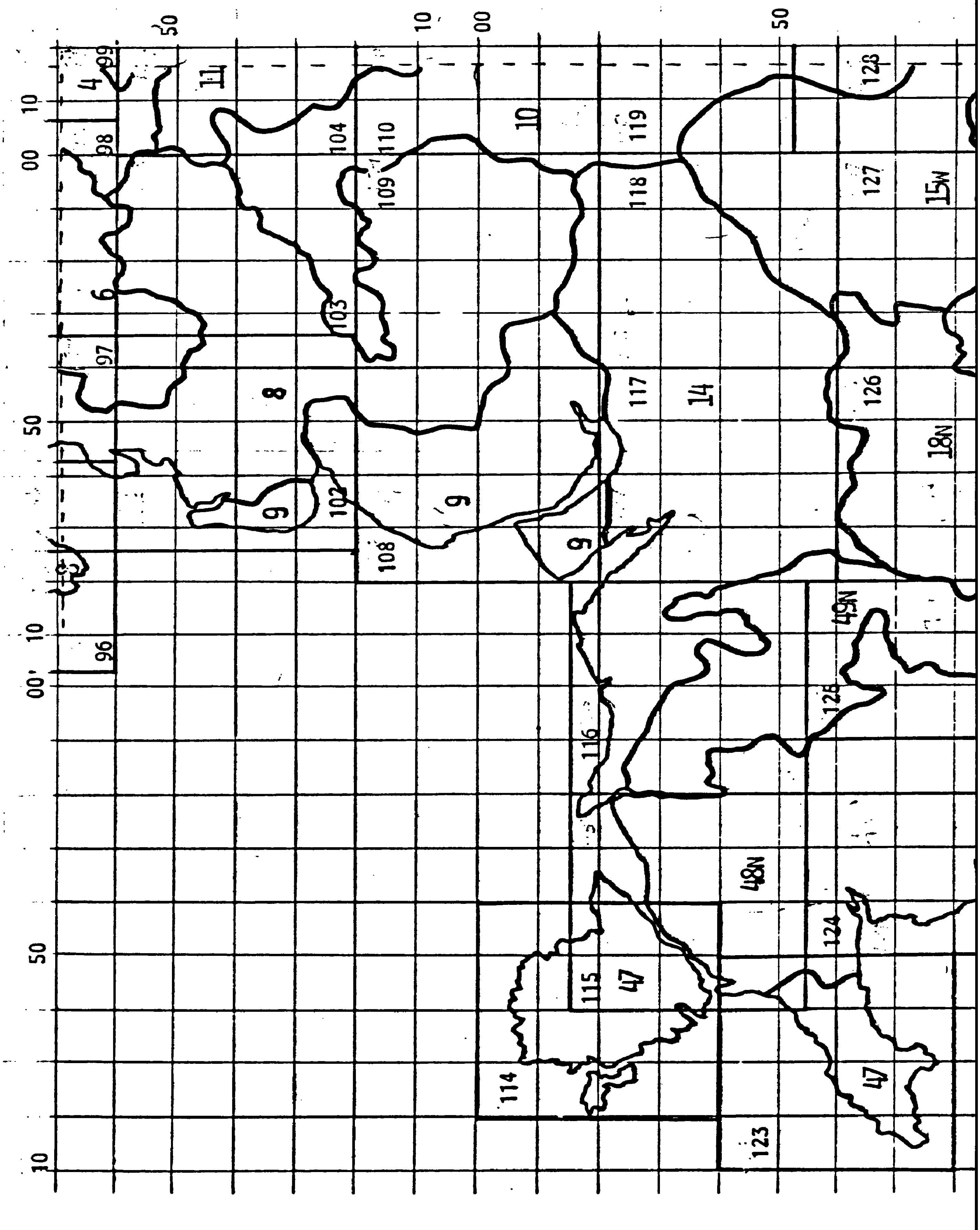


Fig.5 Eastern England

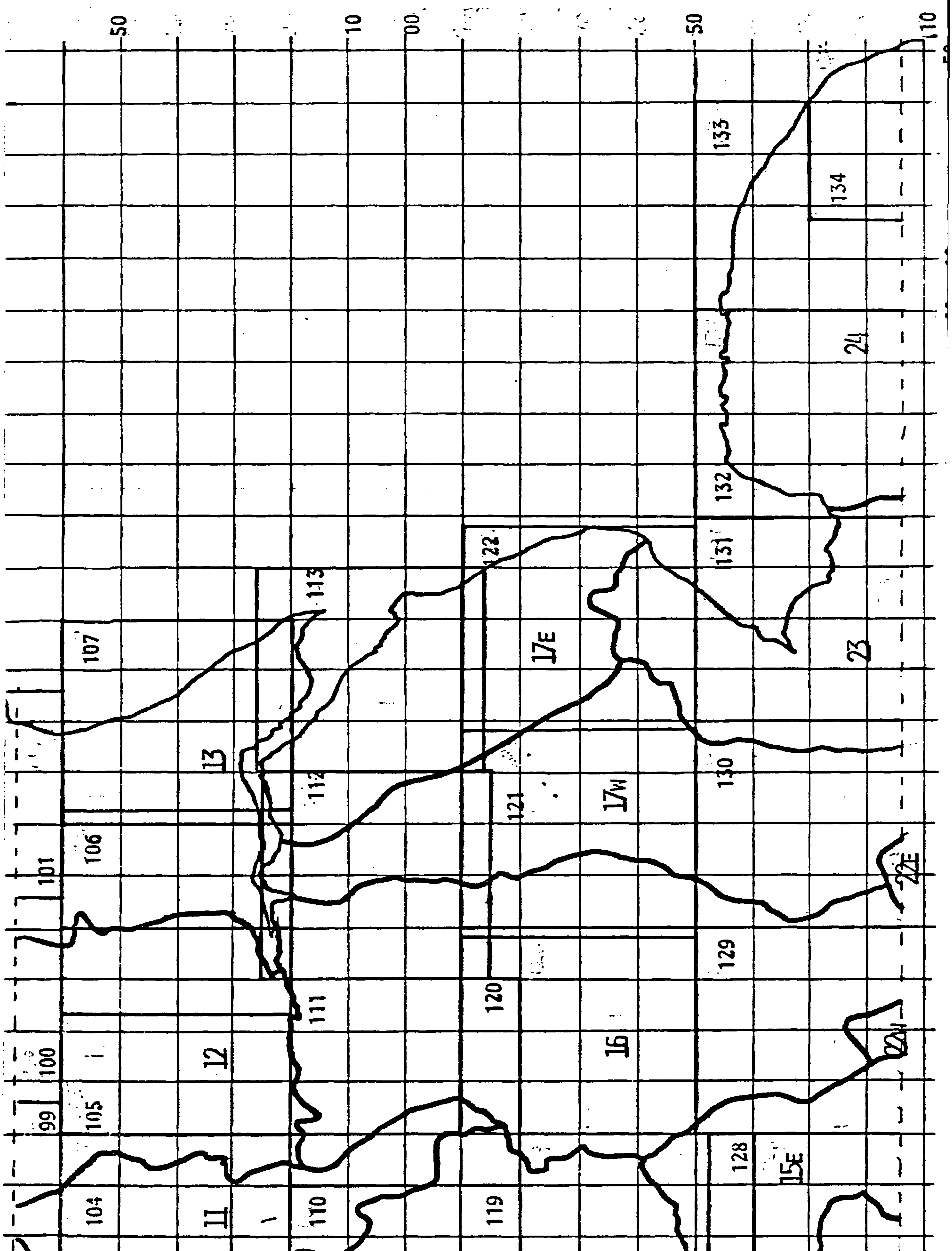


Fig.6 Wales

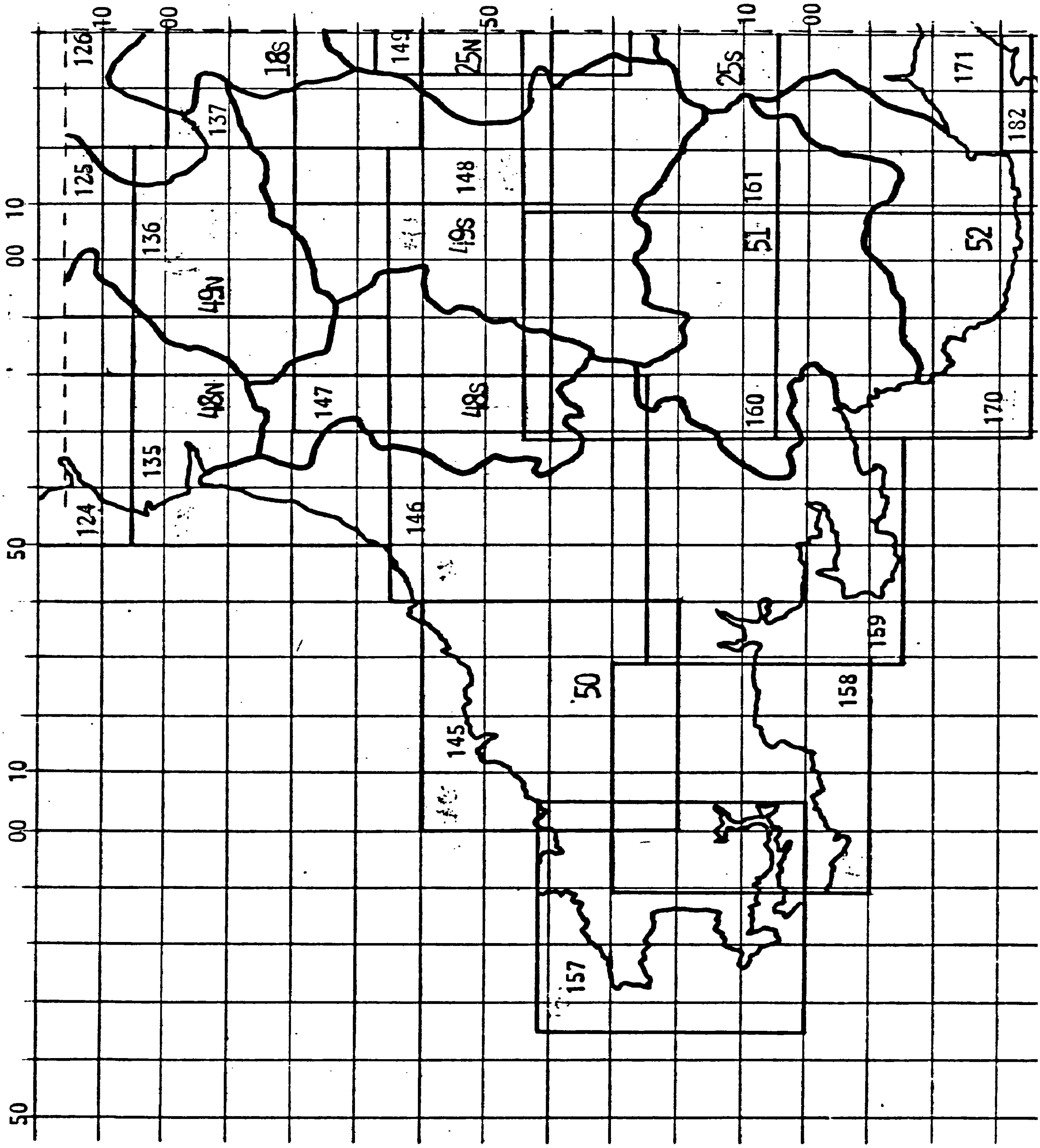

126
125
124
137
136
135
18S
49N
48N
147
146
145
149
25N
148
49S
48S
50
157
25S
161
51
160
158
159
171
182
52
170

Fig.7 Midlands

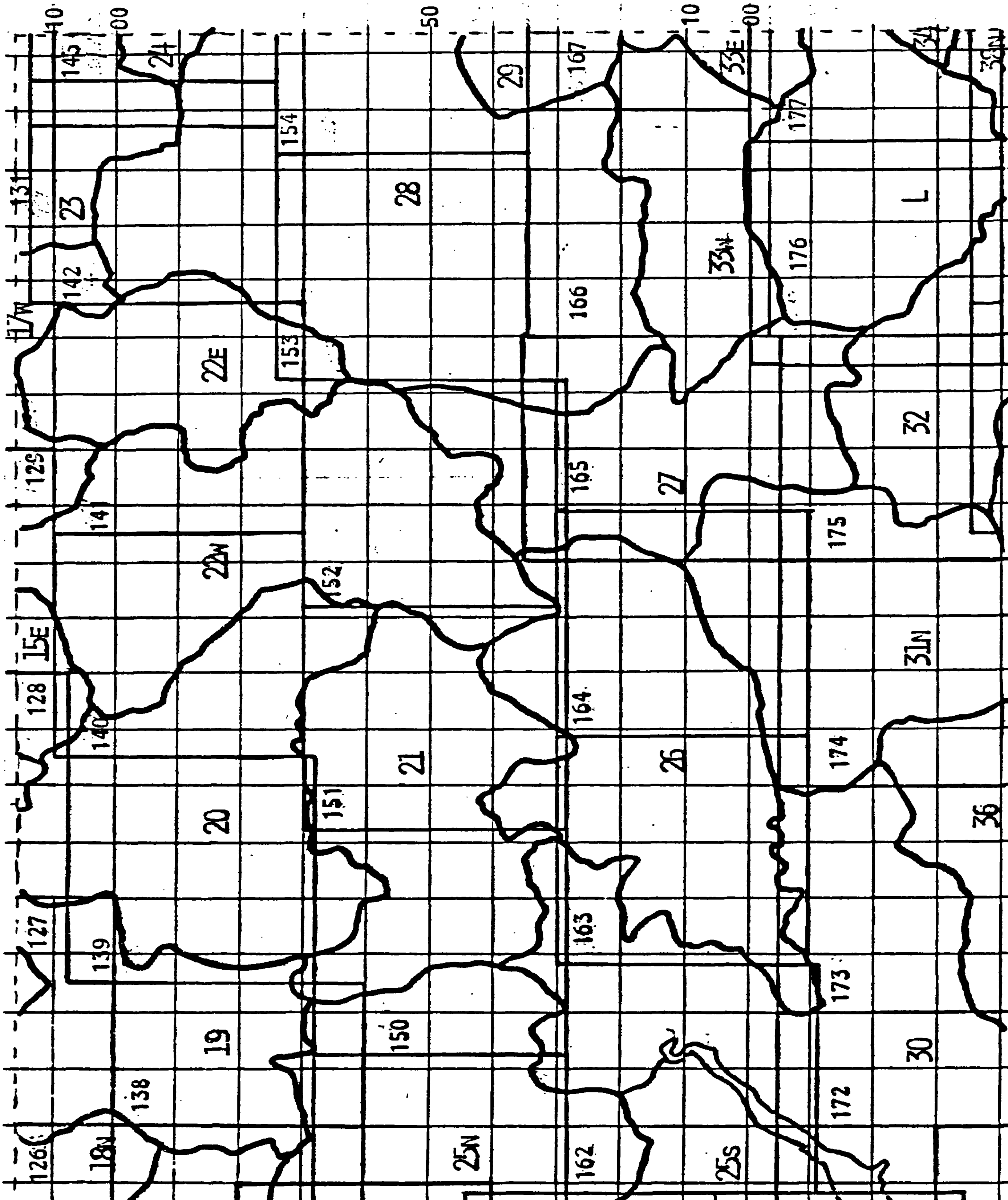


Fig.8 East Anglia

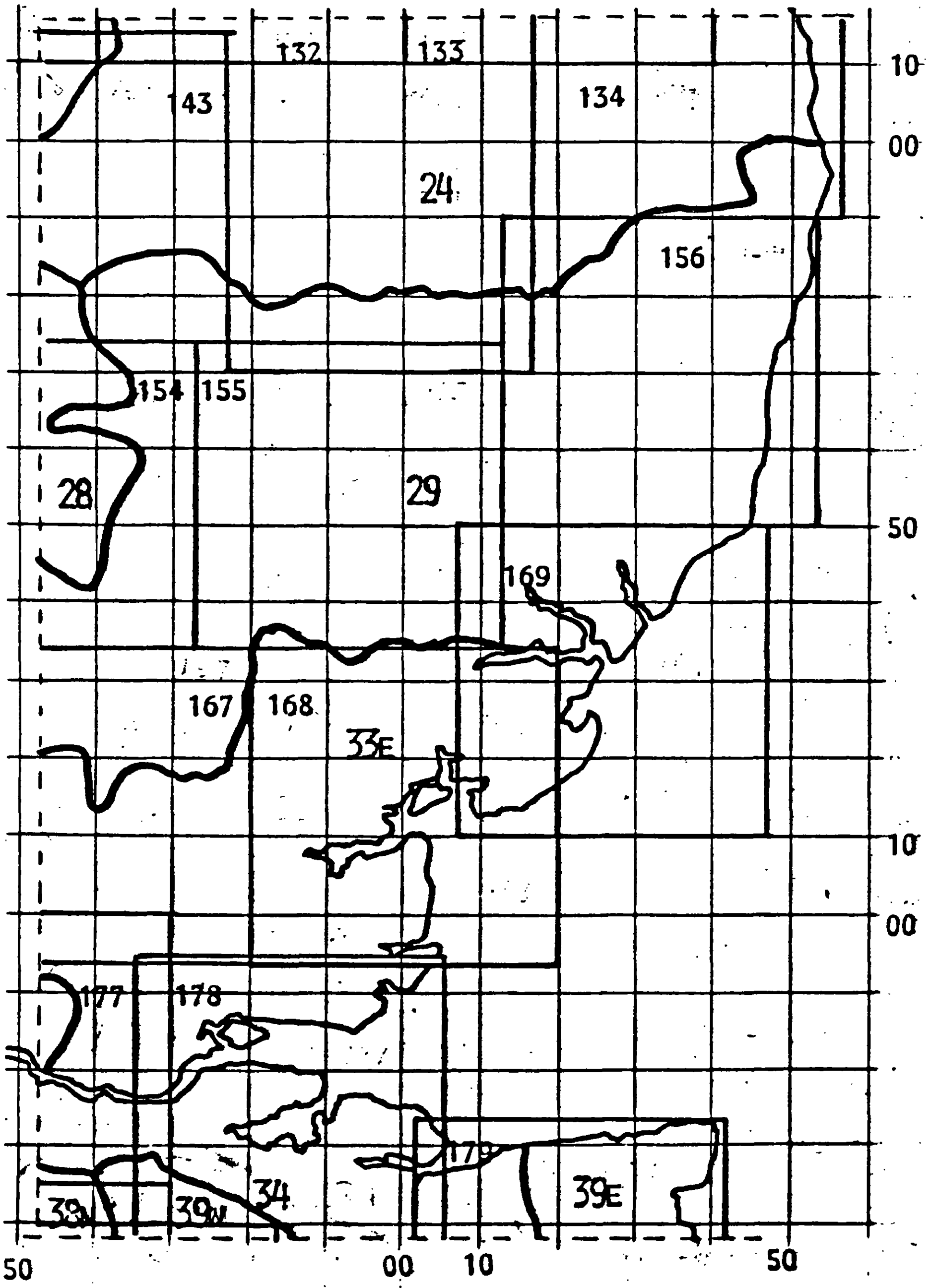


Fig.9 South Western England

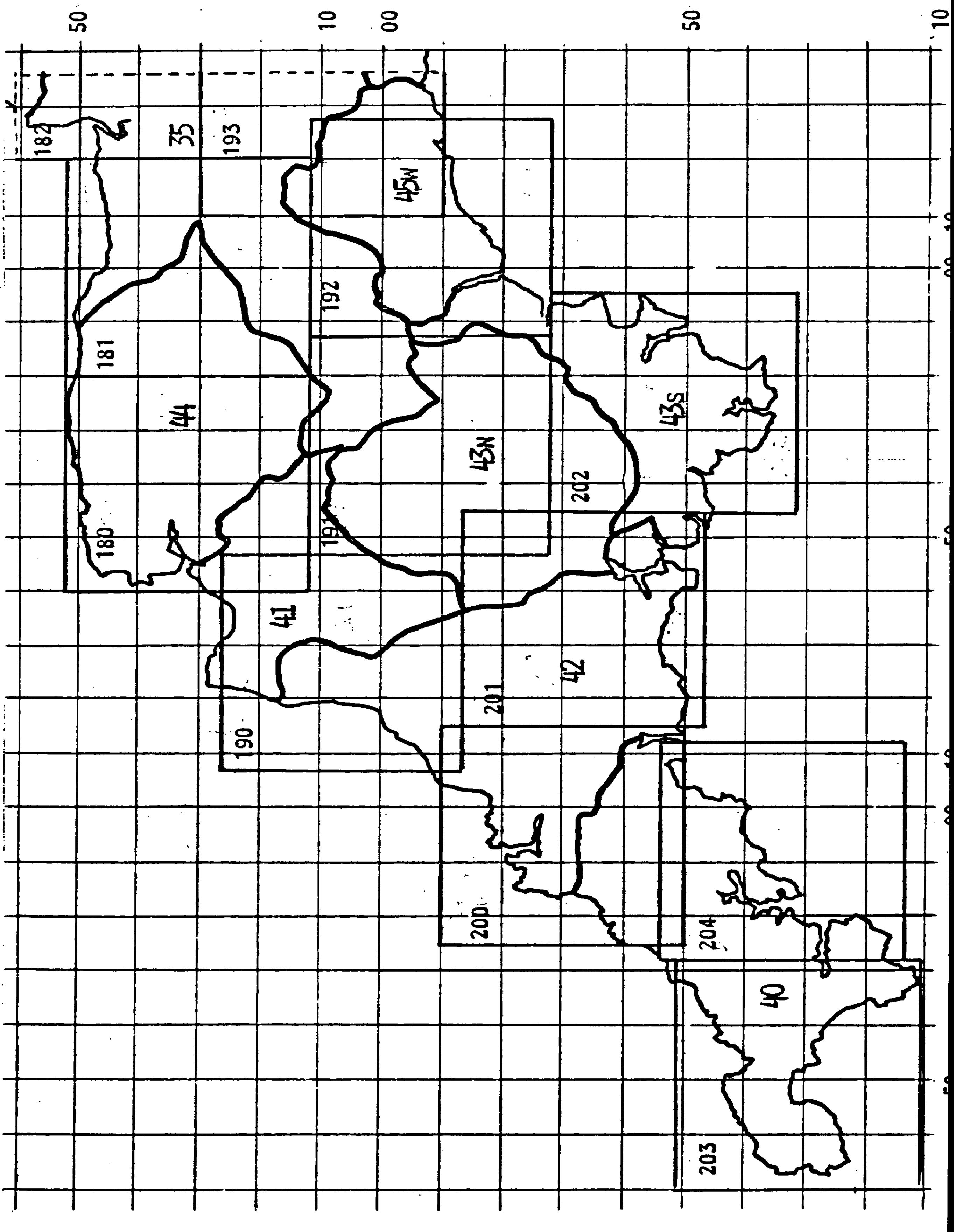


Fig.10 <u>Southern England</u>

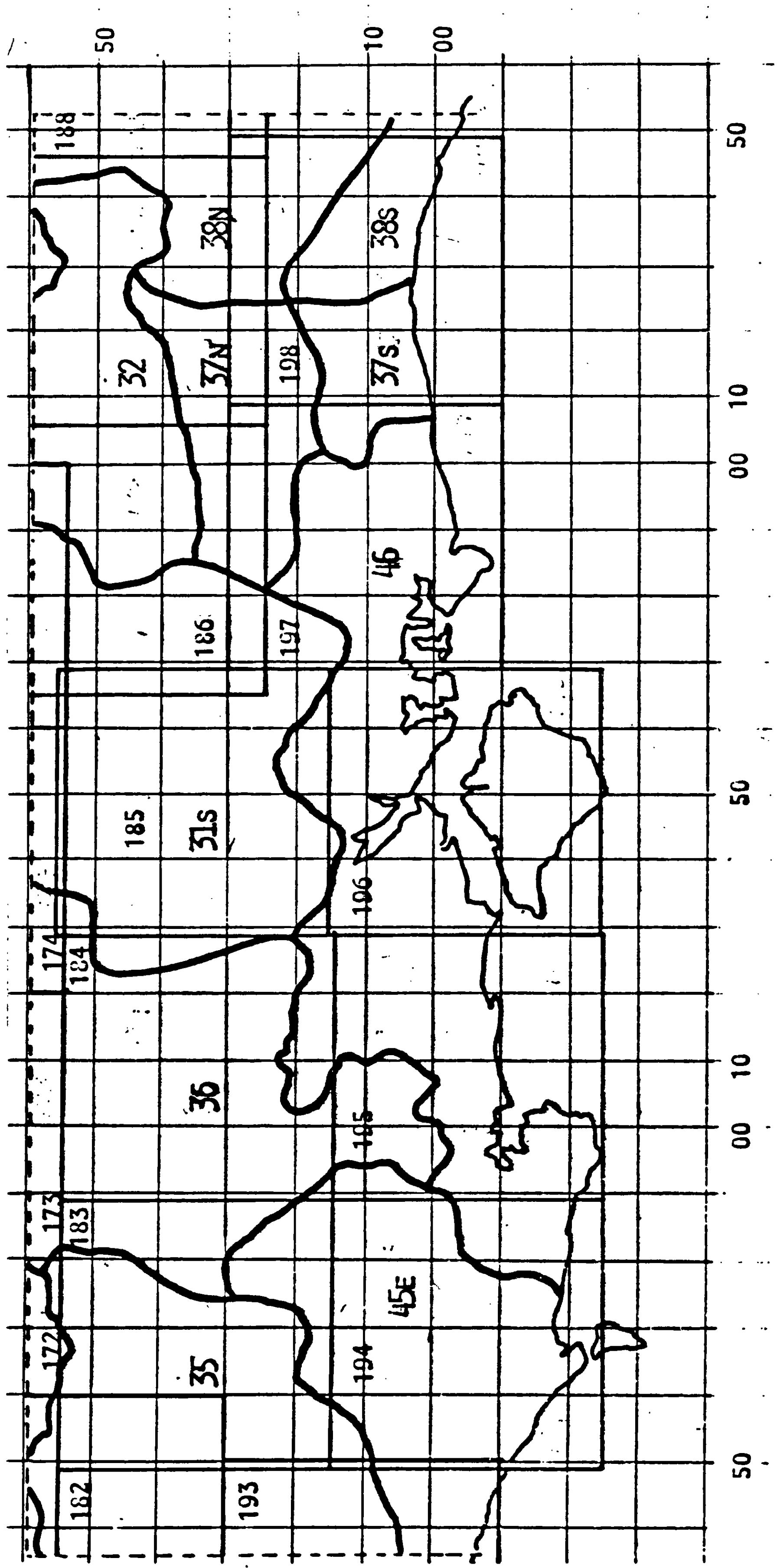
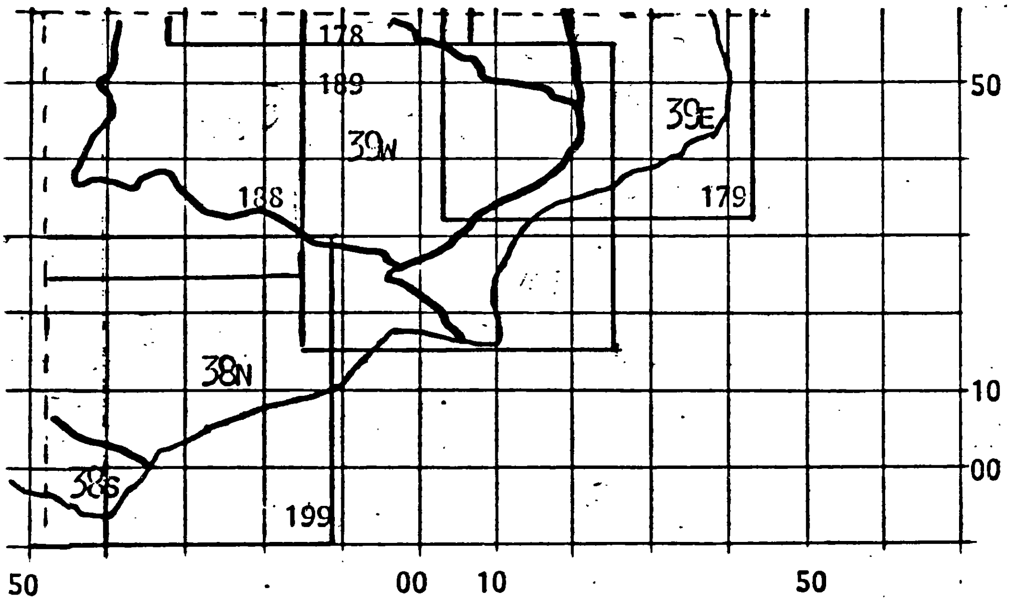


Fig.11 <u>South Eastern England</u>



Plant hardiness (hardiness) is recorded on Plantbase in terms of these zones, thus allowing you to select plants which can be expected to survive a meteorologically average winter at your planting site.

2.3 Zonation of 10 Year Extreme Winter Cold

Climatebase retrieval name = hardiness_ex_0-75m
hardiness_ex_75-150m
hardiness_ex_150-225m
hardiness_ex_225-300m
hardiness_ex_300-375m

Corresponding topic on Plantbase = hardiness

This topic records for each reference area the intensity of winter cold likely to be experienced in a 10 year extreme winter.

The information is recorded via a zone rating derived from the scale 1 (coldest) to 16 (warmest).

Plant hardiness (hardiness) is recorded on Plantbase in terms of these zones, thus allowing you to select plants which can be expected to survive a 10 year extreme winter at your planting site.

2.4 Microclimatic Adjustments to Winter Cold

The following series of microclimatic adjustments can be included in the select line in order to produce a revised prediction of the winter cold status of the planting site.

In the following example the users planting site is in the base of a valley in an urban centre, 1 km from the coast. He wants to know what the likely intensity of winter cold will be when these factors are taken into account. To do this he should type:-

"   " 10 select hardiness_ex_0-75m + valley_adjust +
urban_adjust + coastal_adjust

The inclusion of the + signs tells the computer to add the values for the microclimatic factors to the hardiness_ex_0-75 rating thus producing a more realistic picture of likely winter cold at the site.

2.4.1 Microclimatic Adjustments for Valley Bottoms

bottom

Climatebase retrieval name = valley_adjust

Valley bottoms and low lying area surrounded by higher ground act as a collection point for cold air, and experience far lower temperatures than would otherwise be expected.

2.4.2 Microclimatic Adustments for Urban Sites

Climatebase retrieval name = urban_adjust

As a result of the orientation and physical properties of building materials, solar energy is stored in the fabric of cities during the day, and released at night to create heat islands. All cities of 100,000 people and more generate heat islands that significantly elevate temperatures on frosty winter nights.

2.4.3 Microclimatic Adjustment for Coastal Proximity

Climatebase retrieval name = coast_adjust

Due to the heat storage capacity of oceans, and the coastal circulation systems that these generate, a coastal strip approximately 3km wide experiences significantly higher winter minima than adjacent inland areas.

2.4.4 Microclimatic Adjustments for Sloping Sites

Climatebase retrieval name = slope_adjust

Cold air is heavier than warm air, and as a result tends to flow down in slope to the lowest levels where it collects. (See 2.4.1). Sloping sites of 15 degrees or more which are above the level of cold air pooling and where air drainage is not impeded by buildings or other structures are likely to experience less severe winter minima.

2.4.6 Microclimatic Adjustments for Wall Proximity

Climatebase retrieval name = wall_adjust

Walls constructed of masonry type materials such as stone, brick or concrete act as solar collectors and store solar radiation as heat. This heat is released over the course of the night and elevates the temperature of a volume of air adjacent to the wall surface. The width of the modified volume of air is considered to be 30cm.

This microclimate adjustment does not generally apply to north facing walls.

2.5 Zonation of Growing Season Solar Radiation

Climatebase retrieval name = solar_radiation_0-75m
solar_radiation_75-150m
solar_radiation_150-225m
solar_radiation_225-300m
solar_radiation_300-375m

This topic records for each reference area the intensity of solar radiation likely to be experienced in an average growing season.

This information is recorded via a zone rating based upon the scale 1 (lowest) to 4 (highest).

Plant response to light (flower_sun to flower_sun-shade and growth_sun to growth_sun-shade) is recorded on Plantbase in terms of these zones allowing you to select plants which can be expected to perform satisfactorily in the solar radiation levels experienced at your planting site.

2.6 Microclimatic Adjustments to Growing Season Solar Radiation

The following series of microclimatic adjustments can be included in the select line in order to produce a revised estimate of the solar radiation status of the planting site.

For an example of usage consult 2.4.

2.6.1 Microclimatic Adjustment for North Walls

Climatebase retrieval name = radiation_north_wall_adj

Plants growing against walls of this aspect intercept only a fraction of the overall solar radiation available to a free standing plant in the open.

2.6.2 Microclimatic Adjustment for South Walls

Climatebase retrieval name = radiation_south_wall_adj

Plants growing against walls of this aspect intercept considerably more solar radiation than that which is available to a free standing plant.

2.6.3 Microclimatic Adjustment for East or West Walls

Climatebase retrieval name = radiation_west_wall_adj

Plants growing against walls of this aspect intercept slightly more solar radiation than is available to a free standing plant.

2.7 Zonation of Growing Season Warmth

Climatebase retrieval name = summer_warmth_0-75m
summer_warmth_75-150m
summer_warmth_150-225m
summer_warmth_225-300m
summer_warmth_300-375m

This topic records for each reference area the summer warmth that is likely to be experienced in an average growing season.

The information is recorded via a zone rating based upon the scale 1 (coldest) to 6 (warmest).

Plant response to summer warmth (warmth_necessary) is recorded on Plantbase in terms of these zones, thus allowing you to select plants which can be expected to perform satisfactorily in the summer warmth regime associated with your planting site.

2.8 Microclimatic Adjustments to Growing Season Warmth

The following series of microclimatic adjustments can be included in the select line in order to produce a revised estimate of the growing season warmth status of the planting site.

For an example of usage consult 2.4.

2.8.1 Microclimatic Adjustments for Coastal Sites

Climatebase retrieval name = warmth_coastal_adj

As a result of the sea breeze circulation system generated by sea-land temperature differentials, coastal locations experience significantly less summer warmth. For the purposes of Climatebase this coastal strip is considered to extend inland for 3km.

2.8.2 Microclimatic Adjustments for Proximity to South and West Walls

Climatebase retrieval name = warmth_south_wall_adj

Plants growing against walls of this aspect will experience considerable greater summer warmth than free standing plants due to the warming of the air volume immediately adjacent to the wall surface. This zone of modified air is considered to extend outwards for 30cms.

2.9 Zonation of Growing Season Soil Moisture Stress

Climatebase retrieval name=

soil_moisture_deficit_0-75m

soil_moisture_deficit_75-150m

soil_moisture_deficit_150-225m

soil_moisture_deficit_225-300m

soil_moisture_deficit_300-375m

This topic records for each reference area the soil moisture stress that is likely to be experienced in an average growing season.

The information is recorded via a zone rating based upon the scale 1 (least stress) to 5 (most stress). Plant response to soil moisture stress (soil_moisture_deficit) is recorded on Plantbase in terms of these of zones, thus allowing you to select plants which can be expected to perform satisfactorily in the summer moisture regime associated with your planting site.

3. Plantbase

3.1 Serial Number

Plantbase retrieval name = snum

This is the primary key for Plantbase, and can be used either in conjunction with, or instead of the plants name in a retrieval statement.

3.2 Plant Botanical Name

Plantbase retrieval name = name

When included in a retrieval statement plant names must be spelt correctly and written out in full. Cultivar names must be enclosed in single quotes in accordance with the cultivar code.In most cases it is more convenient to use snum rather than name when retrieving information on a plant known to be contained within the system.

3.3 Coldest Winter Cold Zone in which a Plant can be Considered Hardy

Plantbase retrieval name = hardiness

Corresponding topics on		
Climatebase	=	hardiness_av_0-75m
		hardiness_av_75-150m
		hardiness_av_150-225m
		hardiness_av_225-300m
		hardiness_av_300-375m
		hardiness_ex_0-75m
		hardiness_ex_75-150m
		hardiness_ex_150-225m
		hardiness_ex_225-300M
		hardiness_ex_300-375m

Hardiness is recorded for each plant on the system via the 1 (coldest) to 16 (warmest) zones associated with the corresponding topics. Hardiness ratings are estimates, actual hardiness may vary according to plant age, physiological condition, and environmental conditions.

It can be assumed that a plant is unlikely to experience damage greater than leaf scorch or tip death in the zone in which it is listed as hardy.

3.4 Lowest Growing Season Solar Radiation Zone in Which a Plant can Flower Satisfactorily in Sun, Light Shade, Semi-Shade, Shade, and Full Range

Plantbase retrieval name = flower_sun
flower_inter-sun
flower_inter-shade
flower_shade
flower_sun-shade

Corresponding topics on Climatebase = solar_radiation_0-75m
solar_radiation_75-150m
solar_radiation_150-225m
solar_radiation_225-300m
solar_radiation_300-375m

Flowering performance in response to localised shadeis recorded in terms of the 1 (lowest) to 4 (highest) solar radiation zones of Climatebase. The zone recorded for each plant represents the lowest zone in which that plant can perform satisfactorily. When irrespective of overall radiation zone a plant cannot perform satisfactorily in the given category of localised shade this is recorded as -1.

Avoid using the relational operator $<$ or $<=$ in conjunction with these topics.

3.5 Lowest Growing Season Solar Radiation Zone in Which a Plant can Grow Satisfactorily in Sun, Light Shade, Semi-Shade, Shade, and Full Range

Plantbase retrieval name = growth_sun
growth_inter-sun
growth-inter-shade
growth_shade
growth_sun-shade

Corresponding topics on
Climatebase = (as for 3.4)

Vegetative growth performance in response to localised shade is recorded in terms of the 1 (lowest) to 4 (highest) solar radiation zones of Climatebase.

The zone recorded for each plant represents the lowest zone in which that plant can perform satisfactorily. When irrespective of the overall radiation zone, a plant cannot perform satisfactorily in the given category of localised shade this is recorded as -1.

Sun plants will generally grow satisfactorily in all higher zones than the zone given, whilst shade plants respond in the opposite manner.

Avoid using the relational operators < or <= in conjunction with these topics.

3.6 Lowest Growing Season Summer Warmth Zone in which a Plant can Perform Satisfactorily

Plantbase retrieval name = warmth_necessary

Corresponding topics on
Climatebase = summer_warmth_0-75m
summer_warmth_75-150m
summer_warmth_150-225m
summer_warmth_225-300m
summer_warmth_300-375m

Plant performance is recorded in terms of the 1 (coolest) to 6 (warmest) summer warmth zones of Climatebase.

Plants can perform satisfactorily in the zone ascribed to them, and all warmer zones. Where the opposite relationship applies the user is informed via user_lim (3.34) or add_ftur (3.35)

3.7 Maximum Soil Moisture Stress Zone in which Established Plants can Perform Satisfactorily

Plantbase retrieval name = soil_moisture_deficit

Corresponding topics
on Climatebase = soil_moisture_deficit_0-75m
soil_moisture_deficit_75-150m
soil_moisture_deficit_150-225m
soil_moisture_deficit_225-300m
soil_moisture_deficit_300-375m

Plant performance is recorded in terms of the 1 (least stress) to 5 (most stress) soil moisture deficit zones of Climatebase.

Plants will perform satisfactorily in the zone ascribed to them and all less stressful zones.

3.8 <u>Plant Tolerance of Substrate Moisture Regimes</u>

Plantbase retrieval name = water

Assessment is based upon plant tolerance of substrate moisture regime. The moisture regime in which a plant is ajudged to be most satisfactory is recorded.

The following options are recognised:-

1 (Aquatic ,free water)
2 (Marginal ,free water - land interface)
3 (Wet to average)
4 (Average)
5 (Average to dry)
6 (Wet to dry ,full range)

3.9 Plant Tolerance of Wind

Plantbase retrieval name = tol_expos

Assessment of performance has been based on plant resistance to factors such as defoliation, foliage scorch, stunting, and growth malformation.

On Plantbase the following levels of tolerance are recognised:-

3 (high)

2 (average)

1 (low)

Tolerance has been assessed against mean velocities for lowland England and Wales, and at sites at altitude or on Eastern and Western coasts, mean velocities will be higher and plant response correspondingly more exaggerated.

3.10 Plant Tolerance of Compacted Clays

Plantbase retrieval name = tol_comp_clay

Assessment is based on the ability of plants to perform satisfactorily in soils characterised by high bulk densities and low oxygen content. See also 3.8

On Plantbase the following levels of tolerance are recognised:-

3 (high, satisfactory growth probable)

2 (average)

1 (low, satisfactory growth unlikely)

0 (no data available)

3.11 Plant Tolerance of Excessively Free Draining Soils

Plantbase retrieval name = tol_fr_dr_aggr

Assessment is based on the ability to plants to perform satisfactorily in soils characterised by very large particles and extremely limited water storage.

On Plantbase the following levels of tolerance are recognised:-

3 (high, satisfactory growth probable)

2 (average)

3 (low, satisfactory growth unlikely)

0 (no data available)

3.12 Plant Response to Soil pH

Plantbase retrieval name = ph

Plants are recorded on Plantbase in terms of the pH range in which they perform most satisfactorily and do not commonly exhibit pH generated mineral deficiencies.

The following options are recognised:-

1 (acid to neutral ph 3 - 7)

2 (broadly neutral)

3 (neutral to alkaline ph 7 - 10)

4 (complete range ph 3 - 10)

3.13 Plant Tolerance to Air Pollution

Plantbase retrieval name = polu_tol

Assessment relates primarily to plant tolerance of sulphur dioxide and ozone in terms of presence or absence of acute (visual) symptoms.

The following levels of tolerance are recognised:-

3 (high, visual damage rare)

2 (average)

1 (low, visual damage common)

0 (no data available)

3.14 Plant Tolerance of Airborne Salt

Plantbase retrieval name = salt_tol

Assessment relates to plant tolerance of foliar applied sodium chloride, in either coastal or roadside locations.

The following levels of tolerance are recognised:-

3 (high, damage unlikely)

2 (average)

1 (low, damage possible)

0 (no data available)

3.15 Plant Tolerance of Stooling and Coppicing

Plantbase retrieval name = tol_coppice

Tolerance of this operation is assessed on the basis of the plants biological capacity to initiate adventitious or activate dormant buds, and the form of, and rate at which regrowth proceeds.

The following classes of tolerance are recognised:-

2 (high)

1 (low)

0 (no data available)

3.16 Plant Capacity to Self Adhere to Masonry

Plantbase retrieval name = attach_mason

This assessment is based on the plants possession of structures such as adhesive tendrils, suckers, or aerial roots which allow the plant to adhere to rough masonry type surfaces.

The following options are recognised:-

1 (self adhering to walls)

2 (require provision of additional support)

3.17 Plant Leaf Fall Characteristics

Plantbase retrieval name = lf_fall

Assessment is based upon volume produced and decomposition characteristics of woody plant leaves.

The following options are recognised:-

3 (problem, large becoming mucilaginous)

2 (average)

1 (no problem, small remaining dry)

3.18 Plant Ability to Tolerate Vandalism

Plantbase retrieval name = vandal_tol

Assessment is based on the presence or absence of the following characteristics:
Rapid establishment, ability to quickly replace damaged parts, flexible, non brittle branch structure, dense growth and protective structures such as thorns.

The following levels of tolerance are recognised:-

3 (high)

2 (average)

1 (low)

0 (no data available)

3.19 <u>Plant Tolerance of the Selective Herbicide Dichlobenil Applied Pre-establishment</u>

Plantbase retrieval name = herb_pre_est_dich

Assessment is based upon plant response to application rates of 4.0 kg/ai/ha applied immediately after planting.

The following levels of tolerance are recognised:-

3 (safe)

2 (limited damage possible)

1 (damage probable)

0 (no data available)

3.20 <u>Plant Tolerance of the Selective Herbicide Lenacil Applied Pre-establishment</u>

Plantbase retrieval name = herb_pre_est_len

Assessment is based upon plant response to an application rate of 1.8 kg/ai/ha (light or sandy sois) to 2.7 kg/ai/ha (clay or organic soils) applied immediately after planting.

The following levels of tolerance are recognised:-

3 (safe)

2 (limited damage possible)

1 (damage probable)

0 (no data available)

3.21 <u>Plant Tolerance of the Selective Herbicide Propyzamide Applied Pre-establishment</u>

Plantbase retrieval name = herb_pre_est_prop

Assessment is based upon response to an application of 1.7 kg/ai/ha applied immediately after planting.

The following levels of tolerance are recognised:-

3 (safe)

2 (limited damage possible)

1 (damage probable)

0 (no data available)

3.22 <u>Plant Tolerance of the Selective Herbicide Simazine Applied Pre-establishment</u>

Plantbase retrieval name = herb_pre_est_sim

Assessment is based upon response to an application rate of 1.1 kg/ai/ha (light or sandy soils) to 1.7 kg/ai/ha (clay or organic soils) applied immediately after planting.

The following levels of tolerance are recognised:-

3 (safe)

2 (limited damage possible)

1 (damage probable)

0 (no data available)

3.23 <u>Plant Tolerance of the Selective Herbicide Dichlobenil Applied Post Establishment</u>

Plantbase retrieval name = herb_est_dich

Assessment is based upon plant response to an application rate of 6.7 kg/ai/ha (light or sandy soils) to 9.2 kg/ai/ha (clay or organic soils) applied to plants that have been growing in situ for at least 2 years.

The following levels of tolerance are recognised:-

3 (safe)

2 (limited damage possible)

1 (damage probable)

0 (no data available)

3.24 Plant Tolerance of the Herbicide Glyphosate Applied Post-Establishment

Plantbase retrieval name = herb_est_gly

Assessment is based upon plant response to an overall application of 2.2 kg/ai/ha made in late August or September to plants that have been growing in situ for at least 2 years.

The following levels of tolerance are recognised:-

3 (safe)
2 (limited damage possible)
1 (damage probable)
0 (no data available)

3.25 Plant Tolerance of the Selective Herbicide Lenacil Applied Post-Establishment

Plantbase retrieval name = herb_est_len

Assessment is based upon plant response to an application rate of 1.7 kg/ai/ha (light or sandy soils) to 3.4 kg/ai/ha (clay or organic soils) applied to plants that have been growing in situ for at least 2 years.

The following levels of tolerance are recognised:-

3 (safe)

2 (limited damage possible)

1 (damage probable)

0 (no data available)

3.26 Plant Tolerance of the Selective Herbicide Propyzamide Applied Post-Establishment

Plantbase retrieval name = herb_est_prop

Assessment is based upon plant response to an application rate of 1.7 kg/ai/ha applied to plants that have been growing in situ for at least 2 years.

The following levels of tolerance are recognised:-

3 (safe)

2 (limited damage possible)

1 (damage probable)

0 (no data available)

3.27 Plant Tolerance of the Selective Herbicide Simazine Applied Post-Establishment

Plantbase retrieval name = herb_est_sim

Assessment is based upon plant response to an application rate of 1.7 kg/ai/ha (light or sandy soils) to 2.2 kg/ai/ha (clay or organic soils) applied to plants that have been growing in situ for at least 2 years.

The following levels of tolerance are recognised:-

3 (safe)

2 (limited damage possible)

1 (damage probable)

0 (no data available)

3.28 Plant Aesthetic Life

Plantbase retrieval name = aesth_life

Aesthetic life is defined as the characteristic span of decorative life before replacement or when feasible, regeneration via stooling or coppicing is required.

The following options are recognised:

1 (less than or equal to 5 years)

2 (5-10 years)

3 (10-20 years)

4 (greater than 20 years)

3.29 Plant Maintenance Demand

Plantbase retrieval name = mainten_input

Assessment of maintenance demand associated with a plant has been based upon factors such as; pruning requirements susceptability to weed invasion and pests and diseases, and leaf fall characteristics.

The following levels of maintenance demand are recognised:-

3 (high)

2 (average)

1 (low)

3.30 Ease of Cultivation

Plantbase retrieval name = cultiv_ease

Assessment is based on a plants ability to perform satisfactorily under the sub optimal conditions experienced on many landscape sites.

The following options are recognised:

4 (very easy)

3 (easy)

2 (average)

1 (difficult)

3.31 Primary Role in the Landscape

Plantbase retrieval name = horti_func

Although some plants can be equally satisfactory in widely divergent landscape roles, in many cases a combination of limiting factors define a use for which a plant is particularly well suited.

On Plantbase the following roles are recognised:

a (aquatic)

b (barrier plant)

g (ground cover, including shrub massing = 1m)

m (shrub massing)

p (shelter belt, woodland or urban forest)

s (specimen)

t (turf)

w (wall plant, includes climbers)

3.32 Tolerance of Planting Depth

Plantbase retrieval name = pltng_depth

This topic refers to the depth of soil over the apex of planted bulbs and corms that is most satisfactory for plant growth and development.

The following options are recognised:-

4 (15 - 20cm)

3 (10 - 15cm)

2 (5 - 10cm)

1 (0 - 5cm)

3.33 Water Depth for Aquatic Plants

Plantbase retrieval name = depth_water

This topic refers to the depth of water over the rhizomes of aquatic and marginal plants most satisfactory for plant growth and development.

The following options are recognised:-

5 (60 - 90cm)

4 (30 - 60cm)

3 (15 - 30cm)

2 (5 - 15cm)

1 (0 - 5cm)

3.34 Factors Limiting Plant Usage in the Landscape

Plantbase retrieval name = user_lim

Information on a plants critical deficiencies are recorded in the form of a section of text.

NOTE: This topic should always be included in the select line before a selection decision is finalised.

3.35 Additional Features

Plantbase retrieval name = add_fturs

Information not readily covered by other topics is recorded in the form of a section of text.

NOTE: This topic should always be included in the select line before a selection decision is finalised.

3.36 Height and Width of Mature Specimens in Britain

Plantbase retrieval name = height
width

This assessment is based upon a plants typical dimensions at maturity in the context of an average landscape site, and not the relatively ideal conditions associated with "record" specimens.

Height and width are recorded in centimetres.

3.37 <u>Height and Width of Mature Specimens in Britain After 10 Years Growth</u>

Plantbase retrieval names = height_10

width_10

This assessment is based on the criteria in 3.36

Height and width are recorded in centimetres

3.38 <u>Annual Extension Growth of Woody Plants</u>

Plantbase retrieval name = growth_woody

This is assessed for typical shoots which are developing in the predominant direction of growth. i.e apically dominant shoots in upward growing plants, lateral growths in the case of widespreading plants.

The following categories of extension growth are recognised:-

4 (very vigorous, greater than 90cm per year)

3 (vigorous, 60-90cm per year)

2 (average, 15-60cm per year)

1 (slow, less than 15cm per year)

3.39 Annual Extension Growth of Herbaceous Plants

Plantbase retrieval name = growth_herb

Assessment is based upon annual extension of the foliage canopy periphery from the outermost portions of the previous seasons leaf bases or resting buds.

The following categories of extension growth are recognised:-

3 (vigorous, greater than 30cm per year)

2 (average, 15-30cm per year)

1 (slow, less than 15cm per year)

3.40 Leaf Size

Plantbase retrieval name = lf_size

Assessment is based on the typical mature leaves of plants growing under conditions adjudged to be satisfactory for the performance of that species. Size is considered as the distance from leaf apex to the basal junction with the petiole.

The following categories of leaf size are recognised:-

5 (very large, greater than 60cm)

4 (large, 20-60cm)

3 (medium, 5-20cm)

2 (small, 1-5cm)

1 (very small, less than 1cm)

3.41 Density of Plant Foliage Canopy

Plantbase retrieval name = density

Foliage canopy density is assessed on the basis of obstruction of view for plants in the mid range of their aesthetic lives, growing under average soil conditions in a light regime in which they are adjudged to grow satisfactorily.

The following categories of foliage density are recognised:-

3 (total obstruction of view)

2 (partial obstruction of view)

1 (little obstruction of view)

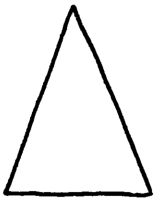
3.42 Overall Plant Form

Plantbase retrieval name = form

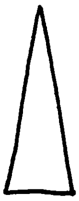
Form is assessed as a silhouette of canopy shape. The presence or absence of a trunk has no influence on plant form.

The following plant forms are recognised:-

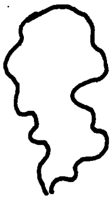
1	2	3	4
narrowly fastigiate	conical fastigiate	broadly fastigiate	upswept fastigiate



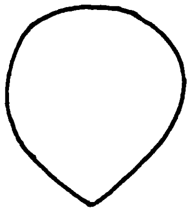
5
conical



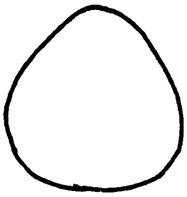
6
narrowly
conical



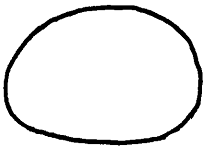
7
irregular
upright



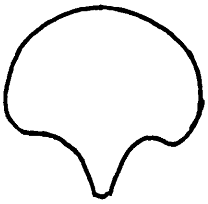
8
upswept
roundhead



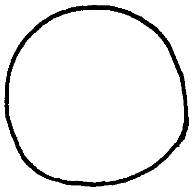
9
inverted
roundhead



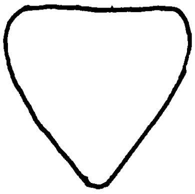
10
squashed
roundhead



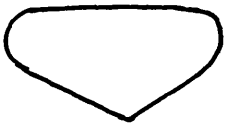
11
fountain
roundhead



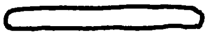
12
lollipop



13
inverted
cone

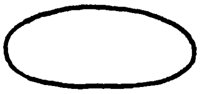


14
squashed
inverted cone



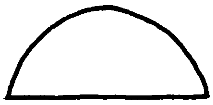
15
carpet

16
upswept
prostrate

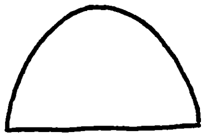


17
ellipse

18
squashed
dome



19
dome



20
tall
dome

21
submerged
aquatic

22
climbing

3.43 Plant Leaf Shape

Plantbase retrieval name = lf_shape

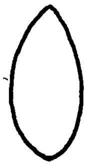
The following leaf shape options are recognised:-

1
absent
reduced or
scale

2
linear
filiferous

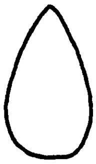
3
lanceolate

4
oblan-
ceolate



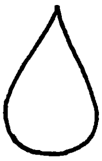
5
elliptical

6
elliptical
acuminate

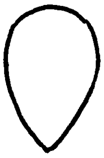


7
ovate

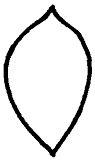
8
ovate
acuminate



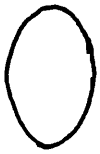
9
deltoid



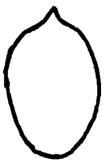
10
obovate



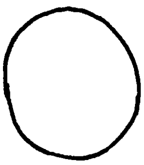
11
obovate
acuminate



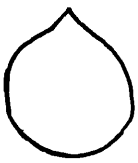
12
oblong



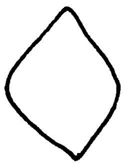
13
oblong
acuminate



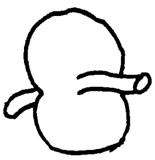
14
orbicular



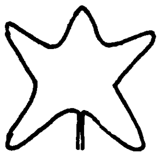
15
orbicular
acuminate



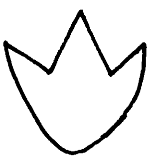
16
rhomboidal



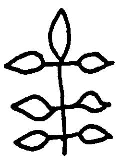
17
perfoliate



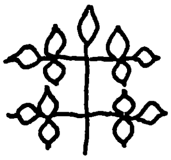
18
palmate
5-7 lobes



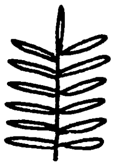
19
palmate
2-3 lobes



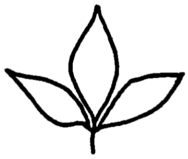
20
pinnate



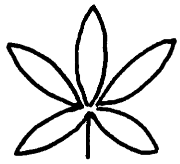
21
bi-pinnate



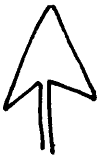
22
pectinate



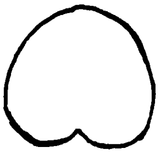
23
trifoliate



24
compound
palmate



25
hastate



26
heart
shaped

3.44 <u>Plant Leaf Margin</u>

Plantbase retrieval name = lf_margin

The following leaf margins are recognised:-

1
entire

2
ciliate

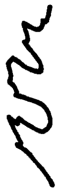
3
pectinate

4
crenate

5
lobed

6
serrate
toothed

7
deeply
incised



8
parted

3.45 <u>Plant Stem Thickness</u>

Plantbase retrieval name = s_diam

Stem thickness is assessed relative to overall plant size for stems younger than 3 years.

The following options are recognised:-

3 (thick)

2 (medium)

1 (thin)

3.46 <u>Overall Plant Texture</u>

Plantbase retrieval name = text

This topic assesses the textures created by the interaction of leaf and branching characteristics, within the overall plant silhouette.

The following overall textural options are recognised:-

a (compact - smooth)

b (compact - angular)

c (compact - billowing)

d (compact - arching)

e (compact - feathery)

f (open - arching)

g (open - angular)

h (open - billowing)

i (open - feathery)

j (semi - pendulous)

k (pendulous)

l (spiky-grasslike)

m (spiky-rosette)

n (tabular)

0 (asymmetrical-angular)

3.47 Plant Branch Tracery

Plantbase retrieval name = tracery

Assessment primarily relates to deciduous species viewed whilst dormant although evergreen species which maintain a relatively open canopy have also been assessed.

The following options are recognised:-

a (stiff - upright)

b (stiff - pendulous)

c (stiff - sparsely branched)

d (stiff - tortuous)

e (stiff - typical decurrent)

f (relaxed - upright)

g (relaxed - sparsely branched)

h (relaxed - tortuous)

i (relaxed - typical decurrent)

j (relaxed - twiggy)

l (typical decurrent)

m (typical excurrent)

n (tabular)

3.48 Plant Stem Texture

Plantbase retrieval name = s_text

Texture has been assessed for shoots of 3 years or younger.

The following options are recognised:-

e (exfoliating)

f (fibrous)

l (lenticular)

p (pubescent)

r (rough-corky)

s (smooth)

t (thorny)

3.49 Plant Bark Texture

Plantbase retrieval name = b_text

Assessment of texture is based upon the characteristic mature bark of a species.

The following options are recognised:-

e (exfoliating)

f (furrowed)

p (plated-scaly)

r (rough-corky)

s (smooth)

t (thorny)

w (warty-smooth)

3.50 Plant Leaf Texture

Plantbase retrieval name = lf_text

Texture is assessed for the dorsal side of mature leaves.

The following options are recognised:-

h (hairy or pubescent)

r (rough or prominent venation)

s (smooth)

3.51 Plant Stem Colour

Plantbase retrieval name = s_col

Stem colour has been assessed against the following base colours and colour combinations:

Base Colour and Plantbase Retrieval Code:			Plantbase Colour Qualifiers: Bright(a)	Dark(b)	Dull(c)	Pale(d)
Black	1					
Blue	2					
Blue-Green	3					
Blue-Grey	4					
Brown	5					
Cream	6					
Cream/Brown	7					
Cream/Grey	8					
Green	9					
Green/Cream	10					
Green/Yellow	11					
Green/White	12					
Green/Grey/White	13					
Green/Pink/White	14					
Grey	15					
Grey/Black	16					
Grey-Brown	17					
Grey-Green	18					
Grey/Orange	19					
Orange	20					
Orange-Brown	21					
Orange-Pink	22					
Orange-Red	23					
Orange-Yellow	24					
Pink	25					
Pink-Red	26					
Purple	27					

Purple-Red	28
Red	29
Violet	30
Violet-Blue	31
Violet-Pink	32
Yellow	33
Yellow-Brown	34
Yellow-Green	35
Yellow/Red	36
White	37
White/Blue	38
White/Grey	39
White/Orange	40
White/Pink	41
White/Red	42
White/Violet	43
White/Yellow	44

- Indicates a blending of two colours

/ Indicates the two colours exist as separate entities

3.52 Plant Stem Colour Qualification

Plantbase retrieval name = s_col_qual

In many cases stem colour deviates from the base colour, and within Plantbase stem colour has been qualified in terms of tonal range or the pattern of colour distribution.

The following qualifiers are recognised:-

a (bright)

b (dark)

c (dull)

d (pale)

e (banded)

f (bloomed)

g (mottled)

h (striated)

Tonal ranges are illustrated in 3.51.

3.53 Plant Bark Colour

Plantbase retrieval name = b_col

Bark colour has been assessed against the base colours and colour combinations illustrated in 3.51

3.54 Plant Bark Colour Qualification

Plantbase retrieval name = b_col_qual

In many cases bark colour deviates from the base colours and has been qualified within Plantbase in terms of tonal range or the pattern of colour distribution.

The following qualifiers are recognised:-

a (bright)

b (dark)

c (dull)

d (pale)

e (banded)

f (bloomed)

g (patchwork)

h (striated)

Tonal ranges are illustrated in 3.51

3.55 Plant Leaf Colour in Spring, Summer, Autumn, and Winter

Plantbase retrieval name = lf_col_spr
lf_col_sum
lf_col_aut
lf_col_win

Typical leaf colour has been assessed for each of the seasons against the base colours and colour combinations illustrated in 3.51

3.56 Plant Ventral Leaf Colour

Plantbase retrieval name = lf_col_vent

Where it makes a prominent contribution to display ventral leaf colour has been assessed against the base colours and colour combinations illustrated in 3.51

3.57 Plant Leaf Colour Qualification in Spring, Summer Autumn, Winter and for Ventral Surfaces

Plantbase retrieval names = lf_col_qual_spr
lf_col_qual_sum
lf_col_qual_aut
lf_col_qual_win
lf_col_qual_ven

In many cases leaf colour deviates from the base colours and has been qualified within Plantbase in terms of tonal range or the pattern of colour distribution.

The following qualifiers are recognised:-

a (bright)
b (dark)
c (dull)
d (pale)

e (mottled)
f (suffused)
g (striated)
h (variegated)

Tonal ranges are illustrated in 3.51

3.58 Plant Flower Colour

Plantbase retrieval name = fl_col

Typical flower colour has been assessed against the base colours and colours combinations illustrated in 3.51

3.59 Plant Flower Colour Qualification

Plantbase retrieval name = fl_col_qual

In many cases flower colour deviates from the base colours and has been qualified within Plantbase in terms of tonal range or the pattern of colour distribution.

The following qualifiers are recognised:-

a (bright)

b (dark)

c (dull)

d (pale)

e (bicoloured)

f (mottled)

g (striped)

h (suffused)

Tonal ranges are illustrated in 3.51

3.60 Plant Fruit Colour

Plantbase retrieval name = fr_col

Typical fruit colour has been assessed against the base colours and colour combinations illustrated in 3.51

3.61 Plant Fruit Colour Qualification

Plantbase retrieval name = fr_col_qual

In many cases fruit colour deviates from the base colours and has been qualified within Plantbase in terms of tonal range or the pattern of colour distribution.

The following qualifiers are recognised:-

a (bright)

b (dark)

c (dull)

d (pale)

e (bicoloured)

f (bloomed)

g (mottled)

h (suffused)

Tonal ranges are illustrated in 3.51

3.62 Plant Leaf Scent

Plantbase retrieval name = lf_scent

Leaf scent is assessed by gentle handling.

The following options are recognised:-

y (present)

n (absent)

3.63 Plant Flower Scent

Plantbase retrieval name = fl_scent

Flower scent is assessed under still conditions at a distance of 1m from the plant.

The following options are recognised:-

3 (strong)

2 (moderate)

1 (weak or absent)

Species whose flower scent is commonly discernable at 5m or greater are noted under add_fturs.

3.64 Plant Stem Reflectivity

Plantbase retrieval name = s_reflect

The following options are recognised:-

s (shiny or light coloured)

d (dull, non reflective)

3.65 Plant Leaf Reflectivity

Plantbase retrieval name = lf_reflect

Leaf refectivity is assessed for the dorsal surface of leaves only.

The following options are recognised:-

3 (highly reflective)

2 (average)

1 (dull, non reflective)

3.66 Month in which Flowering Display Commences

Plantbase retrieval name = fl_period

The commencement of flowering is assessed for Southern England and allowance must be made for this in Northern and South Western England.

The following options are recognised:-

1 (January)

2 (Feburary)

3 (March)

4 (April)

5 (May)

6 (June)

7 (July)

8 (August)

9 (September)

10 (October)

11 (November)

12 (December)

3.67 Duration of Flowering Display

Plantbase retrieval name = fl_duration

The following options are recognised:-

4 (very long, greater than or equal to 9 weeks)

3 (long, 6-9 weeks)

2 (average, 3-6 weeks)

1 (short, less than or equal to 3 weeks)

Actual duration of display may vary according to environmental conditions at the planting site.

3.68 Duration of Fruiting Display

Plantbase retrieval name = fr_persist

Fruit display is considered to have finished when the fruits are no longer making a positive contribution to the landscape.

The following options are recognised:-

4 (very long, greater than or equal to 12 weeks)

3 (long, 8-12 weeks)

2 (average, 4-8 weeks)

1 (short, less than or equal to 4 weeks)

Local variations in bird predation and the severity of weather greatly influence the duration of fruiting display and the rating represents a species typical performance.

3.69 Intensity of Display for Plants Overall Form

Plantbase retrieval name = form_intens

Assessment is based upon the contribution the plants overall form makes to the landscape.

The following options are recognised:-

3 (high)

2 (average)

1 (low)

3.70 Intensity of Display for Plant Stems

Plantbase retrieval name = s_intens

Assessment is based upon the contribution a plants stems make to the landscape.

The following options are recognised:-

3 (high)

2 (average)

1 (low)

Assessment relates primarily to deciduous species during the dormant period.

3.71 Intensity of Display for Plant Bark

Plantbase retrieval name = b_intens

Assessment is based upon the contribution a plants bark makes to the landscape.

The following options are recognised:-

3 (high)

2 (average)

1 (low)

3.72 Intensity of Display for Plant Leaves in Spring

Plantbase retrieval name = lf_intens_spr

Assessment is based upon the contribution a plants spring foliage makes to the landscape as a result of its visual and olfactory characteristics.

The following options are recognised:-

4 (exceptional)

3 (high)

2 (average)

1 (low)

3.73 Intensity of Display for Plant Leaves in Summer

Plantbase retrieval name = lf_intens_sum

Assessment is based upon the contribution a plants summer foliage makes to the landscape as a result of its visual and olfactory characteristics.

The following options are recognised:-

4 (exceptional)

3 (high)

2 (average)

1 (low)

3.74 Intensity of Display for Plant Leaves in Autumn

Plantbase retrieval name = lf_intens_aut

Assessment is based upon the contribution a plants autumn foliage makes to the landscape as a result of its visual and olfactory characteristics.

The following options are recognised:-

4 (exceptional)

3 (high)

2 (average)

1 (low)

3.75 Intensity of Display for Plant Leaves in Winter

Plantbase retrieval name = lf_intens_win

Assessment is based upon the contribution a plants winter foliage makes to the landscape as a result of its visual and olfactory characteristics.

The following options are recognised:-

4 (exceptional)

3 (high)

2 (average)

1 (low)

3.76 Average Intensity of Display of Plant Leaves Across the Year

Plantbase retrieval name = lf_intens_av

Assessment is based on the mean of the plants rating in the seasons of the year when it is in leaf.

The following options are recognised:-

4 (exceptional)

3 (high)

2 (average)

1 (low)

3.77 Intensity of Display for Plant Flowers

Plantbase retrieval name = fl_intens

Assessment is based upon the contribution a plants flowers make to the landscape as a result of visual and olfactory characteristics.

The following options are recognised:-

4 (exceptional)

3 (high)

2 (average)

1 (low)

3.78 Intensity of Display for Plant Fruits

Plantbase retrieval name = fr_intens

Assessment is based upon the contribution a plants fruits make to the landscape as a result of visual and olfactory characteristics.

The following options are recognised:-

4 (exceptional)

3 (high)

2 (average)

1 (low)

3.79 Contribution of the Whole Plant to the Landscape in all of the 12 Months of the Year

Plantbase retrieval name = m_eff

This assessment is based upon a compilation rating of the components of plant display for each month of the year. The rating is recorded as a 12 digit score, representing performance in January through to December. Performance in each month is based on the following assessment model.

9 (maximum display possible)

8

7

6

5 (display of average plant in leaf)

4

3 (display of average deciduous woody plant when dormant)

2

1

0 (minimum display possible, i.e absence of plant)

3.80 Average Contribution of the Whole Plant to the Landscape Across the Year

Plantbase retrieval name = m_eff_av

Assessment is based upon the mean of the overall display ratings for each of the 12 months of the year.

The display options are those illustrated in 3.79

3.81 Contribution of the Whole Plant to the Landscape in the Months of January, February, March, April, May, June, July, August, September, October, November, and December

Plantbase retrieval names = jan_eff
feb_eff
mar_eff
apr_eff
may_eff
jun_eff
jul_eff
aug_eff
sep_eff
oct_eff
nov_eff
dec_eff

Assessment of performance in each individual month is based upon the 0-9 scale of options illustrated in 3.79

3.82 <u>Plant Leaf Persistence</u>

Plantbase retrieval name = lf_persist

The following options are recognised:-

3 (deciduous)

2 (semi-evergreen - tardily deciduous)

1 (evergreen)

3.83 <u>Plant Life Cycle</u>

Plantbase retrieval name = life_cyc

The following options are recognised:-

a (annual)

b (biennial)

c (perennial woody shrub)

d (perennial woody tree)

e (perennial woody climber)

f (perennial semi-woody)

g (perennial non-woody - bulb or herbaceous)

h (perennial non-woody climber)

i (perennial non-woody aquatic)

3.84 Indigenous or Naturalised

Plantbase retrieval name = indig_nat

In addition to truly indigenous species, also included in this assessment are introduced species that have become naturalised in the British Isles.

The following options are recognised:-

y (yes)

n (no)

3.85 Plant Taxonomy

Plantbase retrieval name = taxon

The following options are recognised:-

c (conifers)

d (dicotyledons)

f (ferns and lower plants)

m (monocotyledons)

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